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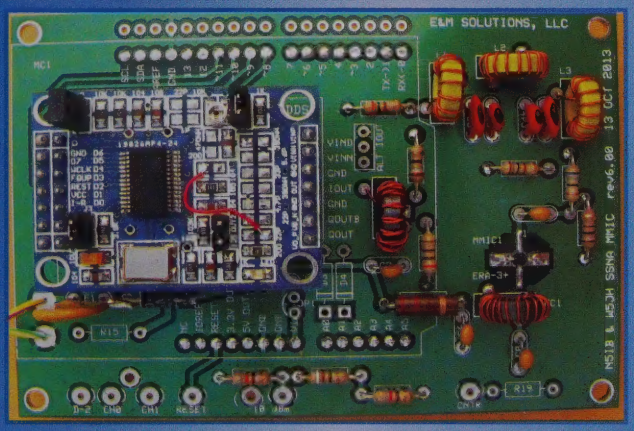
QRP Quarterly

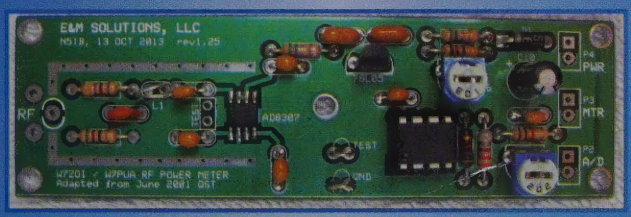
Volume 55 Number 2
Spring 2014

Journal of the QRP Amateur Radio Club International

Arduino & DDS



+ Log Power Meter



= PHSNA (Poor Ham's Scalar Network Analyzer)

- Mystery of the 'Failed State' Electronics, by WØRW
- N6QW Figures Out Antennas for a New QTH
- NM4T Looks at Portable Station 'Go Bag' Gear
- AE6TY's SimSmith Impedance and Circuit Analysis Program Update
- Tune Your St. Louis Loop with NØWL's 'Slide WHiSTLe' Capacitor

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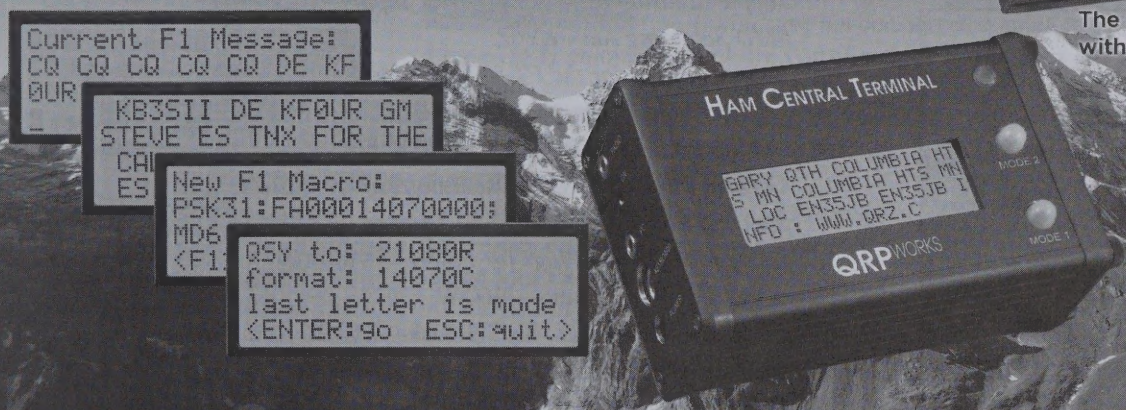

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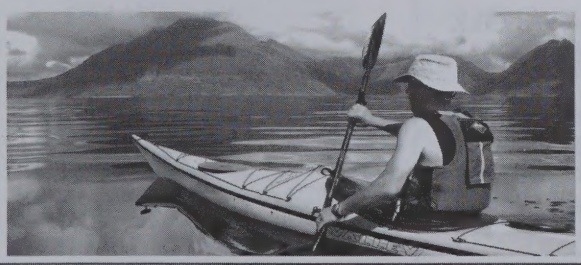

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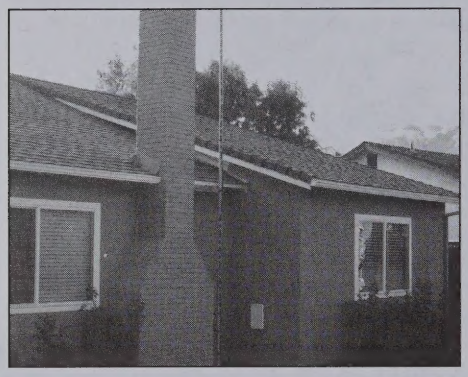

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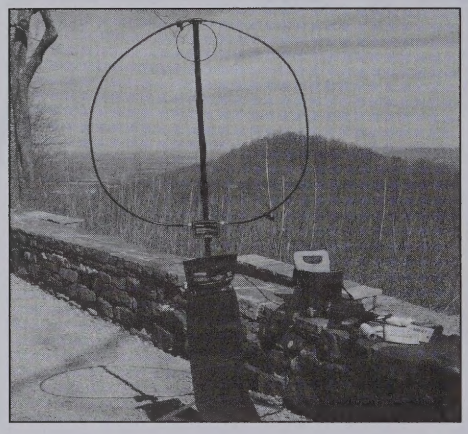

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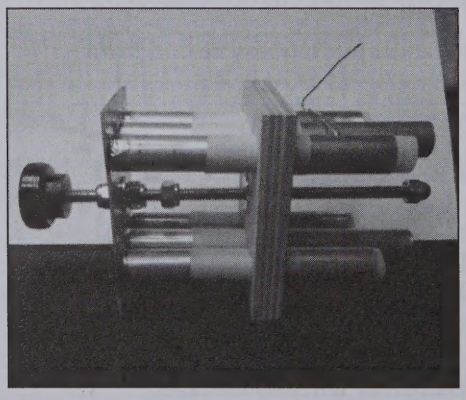

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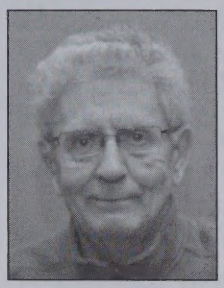


As I write this, I just moved (by myself) and it was something else! Everything got shut down and I was away from everything for about a week—ham radio has not been on my mind as much as I'd like.

Right now I am looking forward to Ozarkcon, which I will write about in the Summer issue, when I will also write about FDIM. I hope you are going to one or the other (or both, as I am). If you go, please introduce yourself. I want to meet more readers.

If you have not considered coming to FDIM, you really should. I have really enjoyed both of my visits for the last two years and am looking forward to this year's meeting in Fairborn (Dayton) OH.

This issue has some great articles, especially the two that are about new Arduino microcontroller technology. One is by Nick, WA5BDU and the other a joint effort by Ben, KK6FUT and Pete, N6QW.

There are also good lessons on antennas of various types, portable gear and software. Of course, WA8MCQ has yet another collection of valuable projects and workshop ideas in the Idea Exchange.

I'd like to thank the Associate Editors, who did more work than usual getting things ready for this issue while I was so busy. Enjoy the issue—I'll bet some of the authors will be at FDIM; maybe you can discuss their articles with them in person.

I don't have any more words of wisdom, with the past couple of months going by too fast. Just keep having fun with QRP!

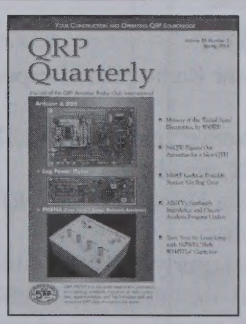
—72/73 de WB9NLZ

Authors Wanted!

QRP Quarterly has established a reputation as an outstanding source for ham radio construction and operating information. It's a great place to "be published."

Have no fear! It isn't your writing experience we want—it's your QRP and homebrewing experience.

QQ is NOT a highbrow, stuffy magazine! Your idea—however simple—just might be exactly what many readers want to know about. Our Editors are dedicated to finding good material to publish, but they also will gladly work with you to get things into shape. To get started, just contact the *QQ* Editor or any of the Associate Editors.



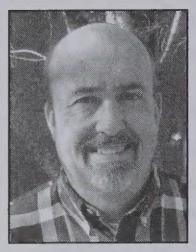
On the Cover

WA5BDU describes a group project that combines a DDS signal source, logarithmic RF detector and an Arduino controller into a swept-signal analyzer. Their finished instrument is dubbed the Poor Ham's Scalar Network Analyzer, or PHSNA. The article begins on page 43.

From the President

Ken Evans—W4DU

president@qrparci.org



Planning for FDIM 2014 is complete! FDIM 2014 dates are Thursday, May 15 through Sunday, May 18. The hotel is now full, but still accepting room reservations on a wait list basis. The FDIM hotel is the Holiday Inn – Fairborn. The room rate is $112.00 per night plus 12.75% tax. This price includes a free breakfast buffet. If you want to get on the wait list, call the Holiday Inn directly at 937-431-4613 (do not call the toll free number!) Calls can be taken between 8 AM and 5 PM Monday - Friday (leave a voice mail at other times and your call will be returned). In addition to putting you on the wait list for the Holiday Inn, they can refer you to other hotels that are within walking distance.

If you haven't already done so, you will need to register for the seminar and/or banquet. To do so, go to the FDIM 2014 web site (http://www.qrparci.org/fdim) and click on "register now." Registration payment is accepted by Paypal or credit/debit card. A PayPal account is not required if people want to pay by card. Information on speakers and all FDIM 2014 activities are at this site.

Board of Directors News

In the winter 2014 *QQ* we announced that three members of Board of Directors of QRP-ARCI will complete their terms on June 30, 2014. The three board members whose terms are expiring are Jay Bromley, W5JAY; Jeff Hetherington, VA3JFF; and Brian Murrey, KB9BVN. Of the members whose terms are expiring, Jay Bromley, W5JAY and Brian Murrey, KB9BVN have chosen to not stand for re-election. Jeff Hetherington, VA3JFF will stand for re-election.

In the winter 2014 issue we called for Board nominations and have received two in addition to Jeff. The two nominees are Rich Arland, K7SZ and Craig Behrens, NM4T. Both Craig and Rich are qualified to serve on the board.

We thank Brian and Jay for their service to the club, but are sure they will be welcome to assist in the future.

We have three qualified candidates for three positions. Per the by-laws:

"If the number of willing candidates is equal to the number of open positions, the candidates shall be considered elected and no vote will be necessary."

Therefore, Rich Arland, K7SZ, Craig Behrens, NM4T and Jeff Hetherington, VA3JFF will assume their 4-year terms on the Board effective July 1, 2014. Their terms will run from July 1, 2014 through June 30, 2018.

For your information, I have included bios on the new members below. Please join me in welcoming Craig and Rich to the Board and for their willingness to serve.

See you all at FDIM in May!

—72, Ken Evans, W4DU
President, QRP ARCI

●●

New Members of the
QRP ARCI Board of Directors

Rich Arland, K7YZ

First licensed in 1963 and have been an active radio amateur for over 50 years. Joined QRP ARCI in 1967. Two terms as a BoD member during the early-mid 1980s. Married to Pat (KB3MCT) for 32 years, and have four children and 6 grand children. Currently living in Dacula, GA. As a member of the USAF, I have worked QRP DX from Japan, England, Germany and the Azores. Spent seventeen years as a vocational educational instructor while employed by the Pennsylvania state Department of Corrections, teaching electronics to incarcerated male inmates.

· First (and ONLY) QRP columnist in *QST* (Jan 2000 to Dec 2003).

· ARRL Field Appointments: Emergency Communications Station and Technical Adviser.

· QRP feature articles with my byline have appeared in *Worldradio*, *QST*, *CQ*, *CQ-VHF*, *QQ*, and *Monitoring Times*.

· Have written four (4) editions of *The ARRL's Low Power Communications, the Art and Science of QRP*. Enjoy homebrewing QRP gear, restoring vintage ham equipment, experimenting with wire antennas, and have given QRP oriented presentations to local Atlanta Metro Area ham clubs and the Dayton Hamvention (five times). Active QRP DXer and enjoy CW contesting using QRP power levels. Elected to QRP Hall of Fame in 2002.

As a member of the BoD I will work diligently toward expanding the QRP ARCI message and spreading the "gospel" of QRP.

Craig Behrens, NM4T

My QRP/Amateur Radio related experience iuncludes:

· QRP ARCI "Active" member # 8137 and long-time ARRL member

· Proud and active North Georgia QRP Club (NoGA) member

· Past QRP Quarterly Editor (40th Anniversary Issues) including: First full-color covers paid for by adding new advertisers; Created rates and implemented paid adds to offset QRP Quarterly publication expenses; Created current magazine layout style still used today

· Many (freelance) QRP-centric articles published in the *QRP Quarterly* and *CQ Magazine*.

· Active >20 years as QRP promoter for field ops and homebrew projects (internationally)

· Assisted with QRP ARCI booths on many occasions (and Elecraft booth at Huntsville Hamfest)

· Active Dayton Hamfest and Four Days in May attendee/support participant

· Created/implemented Two Days in Huntsville with forums (7), special events and door prizes. The event includes: Monte Sano QRP Campout with the Brown-Bag Mystery Antenna Contest (August 2001 with Eric Swartz of Elecraft as contest judge); An Evening of QRP BBQ on Monte Sano, Southern Style with Flying High with QRP Contest (August 2011 with Eric Swartz, of Elecraft as contest judge); BBQ on Monte Sano & QRP Musical

Chairs Contest, Par Electronics celebrity judges; 35th Anniversary Tuna Tin Transmitter Buildathon on Monte Sano with Rex Harper, W1REX of QRPme & Joe Eisenberg, KØNEB, *CQ Magazine* Kit-Building Column Editor

· QRP ARCI Golden Anniversary Jamboree K6JSS activation of Alabama (approx. 200 Qs)

· Created and distributed QRP ARCI Golden Anniversary Jamboree K6JSS award certificates

· Created QRP Skunk Werks Design Group to create "convergence & crossover" radio products

· Ham Radio, Arduino & PICAXE forums; creation of 1st JT65 Rebel transceiver

· Presented Ham Radio and Arduino applications for the Rebel at TEN-TEC's 2013 Hamfest

· 2013 SL-5 team member for Buddies in the Caribbean St. Lucia Suitcase DXpedition

· Active Amateur Radio mentor for DXpedition teams, including residents at DX locations

· Past North Alabama DX Club (NADXC) President and *LongPath* newsletter Editor/Publisher

· Huntsville Amateur Radio Club (HARC) member—QRP portable op. and building Seminars

· Alabama Contest Group (ACG) member that brings QRP into the mix!

· Flying Pigs Club Member #331 and NAQCC Member #5614

· SOTA and Parks-on-the-Air at Monte Sano State Park & Green Mountain Nature Trail Park

· CQ WW SSB Contest Saint Kitts DXpedition

· Built K1, K2, K3, P3, other QRP kits and many field antennas

· Currently writing articles & reviews for *QST* and contributor to ARRL publications

· To present technical forums at 2014 OzarkCon, FDIM, the ARRL Centennial Convention and more.

Personal notes:

· Newly retired Aerospace design engineer/manager (Satellite technology).

· Certified Lean Six-Sigma Black Belt.

· Past Program Management Institute (PMI) member , Professional P.M. certification training.

· Honorable Discharge from USAF and Vietnam Veteran.

· e-mail address: CraigB44@msn.com

Don't Forget FDIM!

See pages 32-33 for information about this year's big event —

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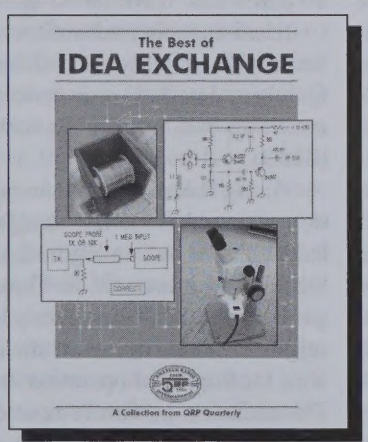

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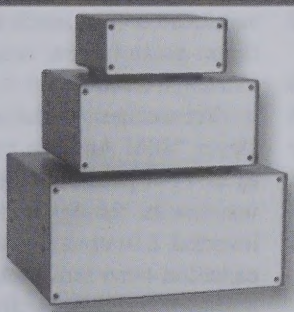

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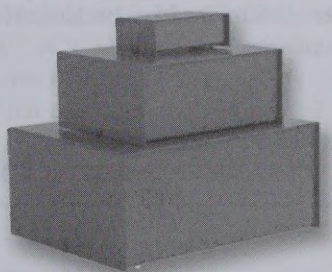

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Idea Exchange

Technical Tidbits for the QRPer

Mike Czuhajewsi—WA8MCQ wa8mcq@verizon.net

In this edition of the Idea Exchange:

Companion MultiBand Antenna—N2CX
Fun With Magnets—ND6T
Homebrewing a Soldering Station—K9AY
10M AM on the Cheap—W4OP
Simple Adjustable Tracking Power Supply—KCØZNG
SMD Soldering Aid—KV6Z
Carrying Strap for the FT-817—W1FMR
A Directional Wattmeter—WØUFO
Cutting Pads in PCB Material—WØUFO
General Purpose Crystal Oscillator/Buffer—KE6TI
Shorting Function for the SMD Adapter—WA8MCQ
Using Male Phone Plugs for Power—WA8MCQ

Companion MultiBand Antenna

Joe Everhart, N2CX, continues the endless string of Quickies he promised me two decades ago with #89—

Here at chez N2CX I'm perennially in search of better antennas for HF QRP CW operation. The design described herein is an attempt at maximizing multiband operation with my KX3. It is intended as a companion for my rig, much as the popular Dr. Who of BBC fame always has a companion. Thus the name Companion MultiBand Antenna or Companion MBA.

As detailed in earlier Quickies, my skywire options are limited due to a yard almost entirely covered by utility wires for my house and for my adjoining neighbor houses. This limits the antennas space to a narrow corridor along one property line. A number of solutions have been tried for the optimum antenna including:

1. Several 66 foot or so end fed wires held aloft by 25 foot masts.

2. A 67 foot open-wire fed inverted vee dipole.

3. A succession of vertical antennas including one of the best choices, a Butternut HF6VX multiband vertical.

All of these were useful but, other than the Butternut, all had limited multiband potential and some were difficult to feed from my house. Alas, the Butternut slowly started disintegrating from weather (hint—water can collect inside the aluminum sections and freeze, causing disastrous mechanical failure).

Yet another interesting possibility is the clever "80M Antenna for Small Gardens" by G7FEK [Ref 1]. It is basically a quarter wave wire for 80 meters set up as an inverted L with a second wire for resonance on other bands. A simplified sketch is shown in Figure 1. Both wires start out as an open wire feeder which feeds two different length elements at the top. By clever selection of the vertical open wire feeder length and of the two top wires, resonance is achieved on a number of the HF bands.

It has several deficiencies for my use. First, it requires three support poles which do not work out in my limited space and it does not work on 20 meters, which would require yet another support pole of some sort. Secondly, for the main bands it is a low impedance antenna which needs a good ground system for efficiency. Close but no cigar.

All in all, the 66 foot end fed wire seems to be what I keep coming back to. The trick is to get it up in the air and properly fed to maximize the radiated signal. I've used it in an inverted vee configuration, a sort-of inverted ell and, what works out best mechanically, an inverted U.

The inverted U shown in Figure 2 began as an extension of an end-fed 20 meter half-square [Ref 2]. I realized that the wire was a total of one wavelength on 20 and a half-wave on 40 so some sort of switched matching network would give me reasonable usability on both bands. A later Quickie detailed a remotely switched matching box to use it on both 20 and 40 [Ref 3].

Along the way the antenna configuration changed from the straight 20 meter half square shown in Figure 2A to the more lopsided U illustrated in Figure 2B. This gave up the 20 meter gain present in the original antenna to elevate the center of the wire for improved operation on 40 meters. The radiation pattern is now quite "interesting."

I used this for quite some time before

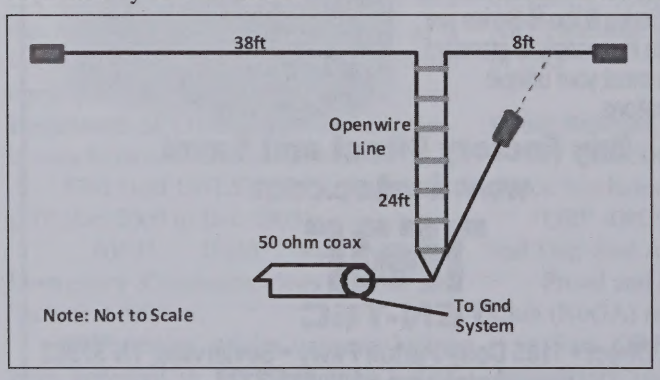

Figure 1—G7FEK multiband antenna.

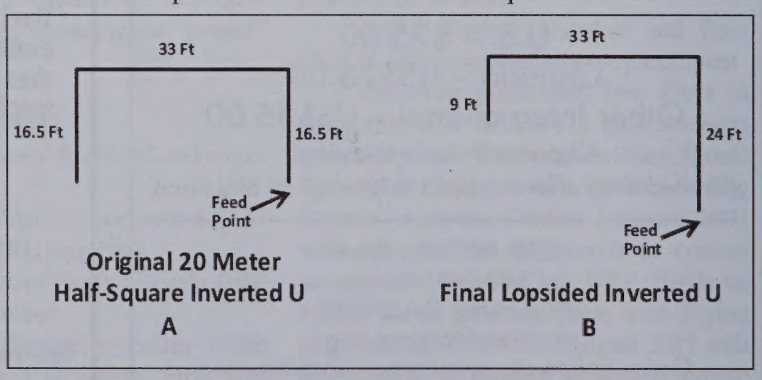

Figure 2—Evolution of the inverted U antenna.

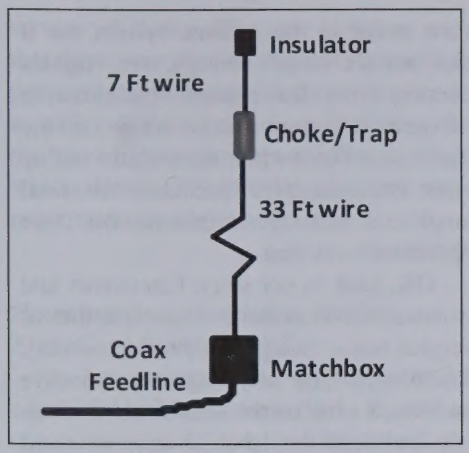

Figure 3—LNR EF-10/20/40 layout.

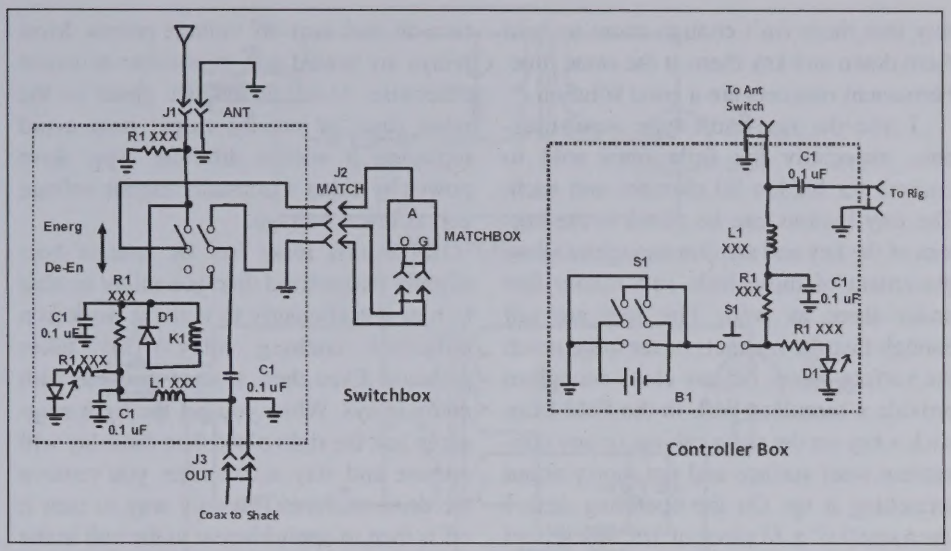

Figure 4—Notional schematic diagrams for the switching scheme.

coming across the LNR EF-10/20/40 (Ref 4), a multiband end fed antenna which, as its name implies, works on 10, 20 and 40 meters. Figure 3 shows the overall construction. It uses a 20 meter half wave wire with a choke/trap and a shorter wire beyond. On 20 it is a true end-fed half wave apparently isolated from the rest of the wire by an apparent parallel self-resonance. The inductance of the choke resonates the entire wire on both 40 and 10 meters as well. The high impedance of the wire is transformed down to about 50 ohms by a broadband matching box.

I first used it as a portable antenna and was so impressed that I began using it as my home antenna. When LNR came out with a smaller, lighter version for portable use I snapped up one of them too. Parenthetically, there have been a number of write-ups on the Internet for clones of the LNR matchbox. Some look like they might work but many suffer from "me-too-ism" and attempt to duplicate the design with little attention to describe how well they work. I may some day try to clone the matcher but for now I'm happy with the relatively low cost of the "real deal."

As noted by several folks on the Internet, the matching network can be used with a half wave wire on any single band from 40 through 10 meters. What's more, I realized, a wire that is a half wavelength on 40 (67 feet long) will also be an even multiple of a half wavelength somewhere in the 20, 15 and 10 meter bands as well. Indeed that's true, though resonances on the higher bands tend to be above the CW portions. However, the SWR is not outlandish and well within the matching range of my KX3's internal tuner. This approaches the ideal antenna for my use.

The sticking point is that it does not give my other two favorite bands, 80 and 30 meters. On 80, the 67 foot wire is only a quarter wavelength with a feed point impedance of only 30-50 ohms (including ground losses). However, if I disconnect the high-impedance matcher and attach the wire directly to my coax feeder I get a decent match on 80 meters. It's even reasonably effective since I use it with the ground radial system left over from when the Butternut vertical was still in one piece. As a bonus, it is also within tuning range on 30 meters. While the resonance point is above the 30 meter ham band, it is within the KX3 tuner range.

The downside of all this is that bandswitching means going out to the antenna to manually change the connections. It's inconvenient but not too bad in warm weather, but has been a real nuisance given the cold winter and frequent ice and snow in the winter of 2013/14.

The answer, naturally enough, is to build something to do the switching remotely from the comfort of the hamshack. The basic design idea is already in existence as described in Ref. 3. A DC control signal is fed through the coaxial feedline to flip a relay at the antenna. Instead of swapping out tuning networks as in the original setup, a relay now swaps out the match box and antenna so that in one setting the matchbox is in line between the antenna and feeder while in the other position the matchbox is bypassed and the feeder connects directly to the feedline. Notional schematic diagrams for the remote switch and the control boxes are provided in Figure 4.

It is hoped that by the time this Quickie appears in print Winter will have loosened its grip on Southern NJ and the antenna design and construction will be completed. If that happens, a sequel to this Quickie will document the final details. It is also intended that detailed results from the installed antenna will be provided as well.

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1. G7FEK 80m Antenna for small gardens: http://www.g7fek.co.uk/software/G7FEK%20antenna.pdf

2. Joe's Quickie No. 52, "The Half Square Plus Antenna," N2CX, included in the Idea Exchange column, *QRP Quarterly*, Winter 2005.

3. Joe's Quickie No. 53, "2-Band HSP Tuner," N2CX, included in the Idea Exchange column, *QRP Quarterly*, Spring 2005.

4. LNR EF-10/20/40: http://www.lnrprecision.com/endfedz-specs/

—de N2CX

Fun With Magnets

Don Cantrell, ND6T, sent these comments about magnets in the shack and shop—

Keys:

Tired of chasing your key around the operating desk? Miniature keys are the most problematic. Some of mine are so

tiny that there isn't enough room to hold them down and key them at the same time. Permanent magnets are a good solution.

I like the rare-earth type super-magnets, especially the little ones sold to crafters for hidden lid closures and such. The tiny buttons can be glued to the bottom of the key and are thin enough to allow placement of those little soft rubber feet under there as well. The feet are tall enough that the magnets never quite reach the surface below but are close enough to provide a herculean pull. In the field I can stick a key on the radio cabinet or any convenient steel surface and not worry about scratching it up. On the operating desk I use a small 6" x 8" piece of 1/8" thick steel rack panel with low profile feet on the underside. I then stick my little novelty keys on that.

Soldering Iron:

I found a great deal on a soldering iron at a recent swap meet: A Weller WTCPS only missing the holder for the iron. Somebody else was parting with an old Archer [Radio Shack] soldering iron holder for cheap. Serendipity! A light touch with a file and the iron slipped right in, comfortably at home. Evidently the holder was designed for someone that didn't constantly bounce about the lab. You needed a good sense of balance to keep it upright with the hot iron in it. Upon inspection I found a thin metal plate underneath but it was lightweight. A set of magnets retrieved from scrap hard drives eagerly snapped to position beneath that base plate where the rubber feet would just keep them clear of the bench top.

My soldering workbench is an ancient metal-topped dining room table. It's quite impervious to solder splashes, dropped tools, and other careless errors. It fits my delicate (OK, bull-in-a-china-shop) work style. Moreover, it is painted steel! That soldering iron holder now has to be pried off the bench to move it.

No glue. No screws. No commitments.

Relays:

Since these critters are primarily electromagnets operating switches, often we can modify relay characteristics by placing a permanent magnet nearby. Reed relays are particularly easy to affect. By carefully and precisely positioning a magnet we can provide a permanent bias to adjust the turn-on and turn-off voltage points. Most relays are sealed and impossible to adjust otherwise. Using a magnet glued to the relay case, or nearby, might help avoid replacing it with a different type. Save power by using a normally higher voltage coil at lower voltage.

If a reed relay has its contact bars slightly magnetized then you might be able to bias it sufficiently to make it work as a polarized latching relay. This takes patience. Even then, it's not possible with many relays. When you get the right magnet in just the right place then the relay will operate and stay active after you remove the drive current. The only way to turn it off is then to apply current to the coil in the opposite polarity. Nice for antenna tuners and such, since power needs to be just a pulse rather than a continual holding current.

Various shapes of ceramic magnets work well here. The larger area and weaker field can be advantageous. I'm not talking about those plastic magnets that you stick on the 'fridge. Those are much too weak.

Isolators:

If you haven't heard of an isolator then you are not alone. These little guys are used mostly at VHF and above. Based on ferrite circulators, a common microwave feed line combiner and directional coupler, circulators are a passive element with at least three ports. Signals into the first port appear at the second with low loss. Signals coming into the second port from the outside world don't appear at the first port, though. Instead, they appear at the third port. And signals into the third port don't show up at the second port: They go to the first port! See? It's directional. The signals circulate from port to port in one direction only. This is handy for combining transmitters to a common transmission line since it keeps each transmitter from seeing the others. You want them just looking at the antenna, not feeding the output stage of other transmitters.

Now, if you put a dummy load on that port #3 then you made that circulator into an isolator. Signal from the transmitter is passed toward the antenna but reflected signal from the antenna just goes to port #3 where it is swallowed by the dummy load. The transmitter always sees a nice perfect load impedance no matter what indiscretions occur in the antenna system. As if that wasn't sweet enough, any signals coming from the antenna (neighboring transmitters in particular) don't go into the transmitter finals where they would mix up some intermodulation products. Yes, final amplifiers make great mixers. We Pixie operators know that.

OK, back to our story. Circulators and isolators are expensive. There are lots of surplus units, though, for little to nuthin'. Trouble is, they are frequency selective and won't work on the ham bands. Pick up one and read the label. It says to avoid magnetic fields. Aha! The ferrite structure is tuned by an internal permanent magnet. I picked one up that was surplus from IMTS service just above 150 MHz, glued an alnico magnet in a sweet spot on the side of it where it tuned it down to our 2 meter repeater output. Works like a champ.

Feeling Lost?

Any time you include magnets in your equipment don't forget that they are there. If you use a compass to navigate then drop your backpack and walk well away from your equipment before taking a reading. Magnetic fields decrease rapidly, diminishing at the cube of the distance compared to the square of the distance that we are familiar with from radiation field strength, but remember that they are there.

Attaching a key with a magnet to your radio just might tune you to another frequency. Permeability Tuned Oscillators are especially affected. Anything with a core is suspect. No big deal. Just keep it in mind and try it out before it becomes important. My friend Clark (WA3JPG), who proofread this for me, relates attaching a key magnetically to his FT817 only to have it wildly shifting frequencies until he realized the cause. See? It can happen to anyone. If you really insist on attaching a key to the rig then consider gluing a thick piece of mu-metal (a high-permeability alloy) on which to attach the key magnets. Old computer hard drives contained those extreme magnetic fields just millimeters from the sensitive magnetic media platters. There may be a lesson there!

[*WA8MCQ note:* I wasn't sure what IMTS was so I asked N2CX. This is his reply: "IMTS was the Improved Mobile Telephone Service. It ran in VHF High Band (and perhaps UHF) and until cell phones arrived it was the mobile telephone

service of choice. The only problem was that there were too few channels (a handful per city) and there was no frequency reuse as with cellular service. I am familiar with the baseband equipment since for a while I was a Harris RF mobile telephone and pager terminal engineer."]

—de ND6T

Homebrewing a Soldering Station

From Gary Breed, K9AY—

A few months ago, my temperature controlled solder station died. It was a cheap import and I considered it sheer luck that it worked well and for a long time—more than 10 years. To replace it, I tried another low-budget soldering station, which was completely unsatisfactory. Next, I tried the Radio Shack Digital Soldering Station (#64-053), which was a so-so performer for my work and was returned.

Then I remembered what I liked best about my old soldering station! It was a perfect fit for tips from the Weller WTCPT station. Most cheap soldering iron tips corrode away in no time, but the Weller tips are very impressive in their longevity. I still had a pretty good collection of tips in various shapes and temperature ratings that had been acquired at hamfests and surplus stores. The WTCPT is a common production line soldering station and I see old units and parts quite often.

So I looked into buying a WTCPT. The price is $150-175 for a new one, but when perusing the manual I saw that the actual temperature control was magnetic-based and located inside the iron. Seeing how simple the power unit was, I realized everything needed was laying around somewhere in my parts collection! A new replacement TC201T iron is $91 at Mouser, so I bought one when I placed my next parts order.

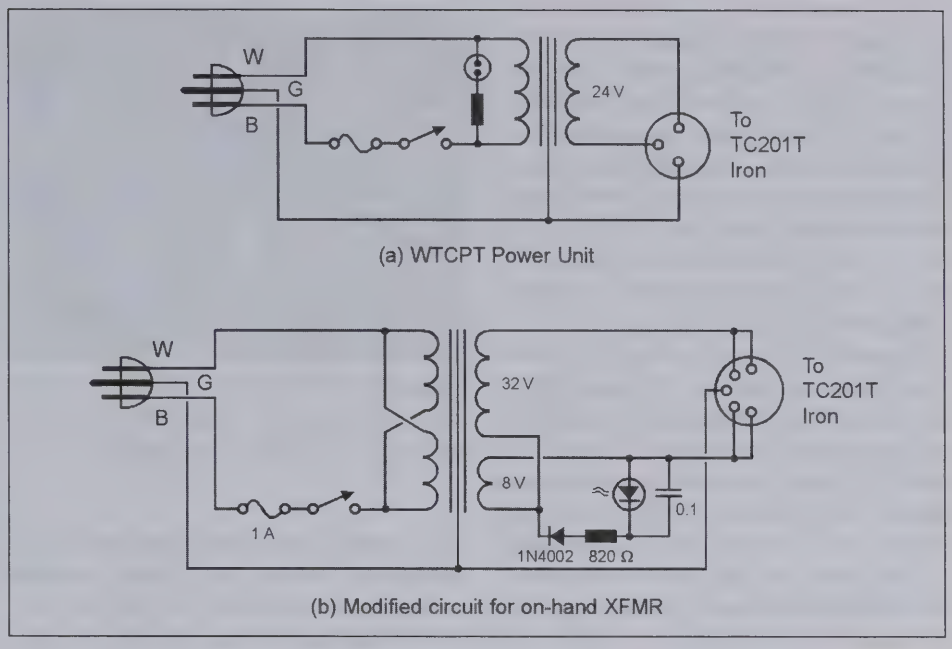

Figure 5—Soldering station power unit schematics: (A) is the factory power unit; (B) is the circuit used to work with the junk box power transformer and DIN connector.

Now it's time to build a "commercial grade" power unit. Figure 5a is the schematic of the Weller WTCPT power unit. It provides a nominal 24 VAC (actual 26 VAC) at about 1.7 A to the 42 watt TC201T iron (isolated from ground), plus a ground connection to the heater barrel and tip. The 120 VAC input is switched and fused, with a neon pilot light.

I had a brand new 24 VDC, 2.5 A power supply acquired at some past hamfest for a couple bucks. It had a high quality transformer, but with a 32 volt secondary to allow for the voltage drop in its linear regulator. Luckily, it also had an 8 volt winding for a 5 volt supply to run its internal circuitry—with the same size wire as the 32 volt winding. All I needed to do was wire the low voltage winding to "buck" the higher voltage and get 24 VAC. Actually, it worked out to 26 VAC! Figure 5b is the final circuit I used. My pilot light is an LED, connected across the low voltage secondary winding.

I wanted a compact and robust package for the power unit. In my "stuff' I found an unused 4x4x4 electrical junction box. At first, it seemed too small, but I realized the

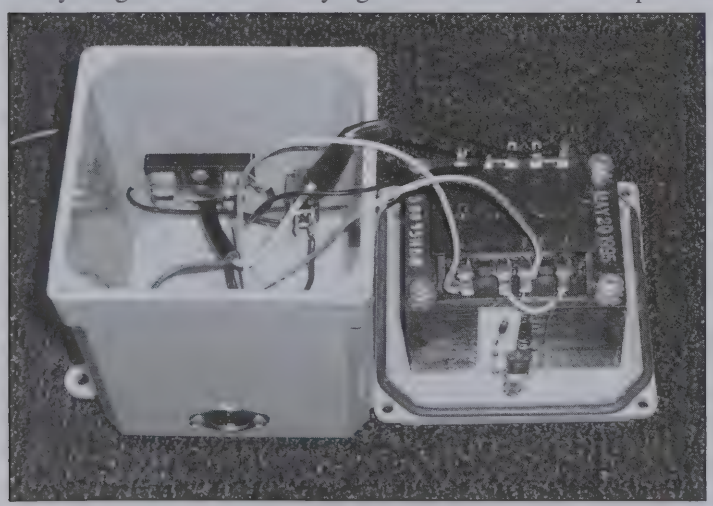

Figure 6—A view inside the homebrew power unit.

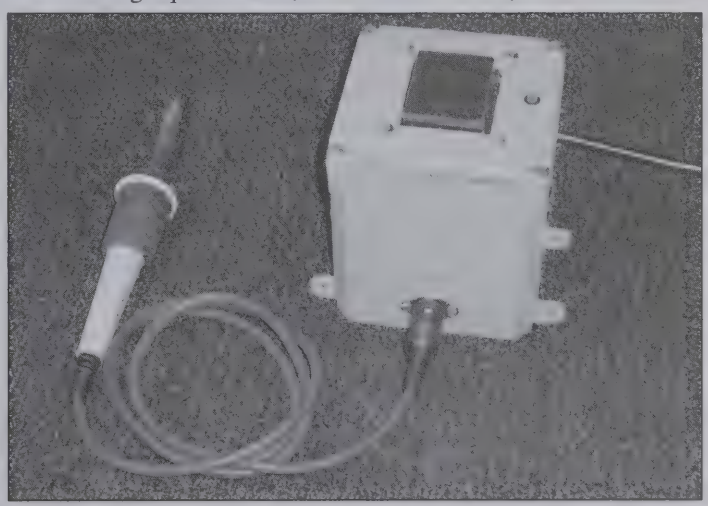

Figure 7—The finished product ready for work.

transformer could be mounted in a cutout on the top. *[A good example of "thinking outside the box." (sorry, I couldn't resist!) —'MCQ]* This left enough room inside for the switch, fuse holder and output connector. I did not have a match for the factory power connector on the iron cord, but I did have 5-pin DIN connector sets on hand. It was a simple matter to cut off the factory connector and install the new one.

Figure 6 is a look inside the box; Figure 7 is the finished unit viewed from the working side. The power cord and on-off switch are on the back side. The WTCPT power unit has an iron holder attached, but I already have a holder and cleaning tray that I've been using for years.

This was a fun little project that saved me $60-$75 and is just as good as the factory unit!

—de K9AY

10M AM on the Cheap

From Dale Parfitt, W4OP—

This project combined some of my favorite aspects of amateur radio: building and vintage gear—if one can call a 1970s radio "vintage."

The idea of converting CB radios to 10M is certainly not new and has been well explored in a number of publications and on the Internet. If the conversion is to SSB, then one expects to spend some time and money in the conversion. That same time and money may be deemed as being poorly spent if the rig is only to be used on the AM portion of 10M (typically 29.0-29.05 MHz). Indeed, in the earlier radios, a separate receive and transmit crystal was required for each channel. However, many of the early 23 channel synthesized radios covered them all with a dozen or so crystals.

Having known one of the principals at E.F. Johnson, I have always had a soft spot for their equipment. I had on my shelves a Messenger 123, a 23 channel mobile rig (Figure 8) that I had bought at a hamfest for a dollar. All of the summer activity on 10M AM got me to thinking about putting that radio on 10M. As I looked at the frequency synthesis scheme shown in Figure 9 it became obvious that if I were to change any one of the crystals in the high oscillator I could cover not only 1 TX/RX channel but 4. (Figure 10 is the schematic of the high oscillator section.)

A quick calculation showed that if I swapped out any of the six high oscillator crystals with one for 34.735 MHz I should be able to work on 29.00, 29.01, 29.02 and 29.04 MHz, both TX and RX. The missing 29.03 "channel" is a result of the six RC hobby channels that were built into the 23 channel CB scheme. It's not a big deal as most activity is centered on 29.00 and 29.01 MHz.

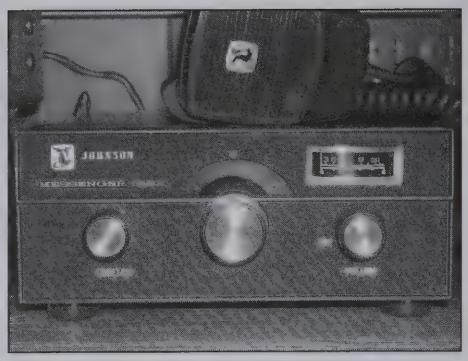

Figure 8—The Johnson Messenger 123 CB radio can be easily converted to 10M AM by changing one crystal.

So the cost of getting 4 RX/TX channels had been reduced from a worst case scenario of 8 new crystals (in the early pre-synthesis days) to one crystal. As I got ready to place my order with International Crystal Mfg., I thought I would do a search on the Internet for that particular frequency. The thought was that any crystal I could find had to be less expensive than a custom made unit.

Initially, nothing turned up until I started looking at the European radio control channels. Channel 79 has a TX frequency of 35.190 MHz. Some more research showed that these radios used an IF 455 KHz below the TX frequency. You guessed it—those crystals are exactly what I required—34.735 MHz. My luck didn't end there. A search of eBay turned up a Chinese vendor that had that crystal for $2 and $2 shipping!

A quick hand count of local hams who would be interested in the project culminated in an order for a dozen crystals (all for the same $2 total shipping). See Note 1 for the eBay source. *[I checked just before the publication deadline and the seller still has the crystals available. —WA8MCQ]*

The local interest started me thinking that perhaps this would also make a nice group or club project- thus the impetus to write about the conversion. When our group had finished their rigs, we all seemed to end up using 10M AM more than 2M FM simplex for keeping in contact, both fixed and mobile, with the added advantage of working DX when the band is open.

The Conversion

I have no idea how many Johnson 123's were sold but they seem to be for sale all over the Internet. In addition to the

Known Models: Johnson Messenger 122, 123A, 123SJ, 130A, 132, 223, 250

	Both RX & TX "A"	RX Only "B"	TX Only "C"
Ch. 1 (26.965)	32.700	6.190	5.735
Ch. 2 (26.975)	"	6.180	5.725
Ch. 3 (26.985)	"	6.170	5.715
Ch. 4 (27.005)	"	6.150	5.695
Ch. 5 (27.015)	32.750	6.190	5.735
Ch. 6 (27.025)	"	6.180	5.725
Ch. 7 (27.035)	"	6.170	5.715
Ch. 8 (27.055)	"	6.150	5.695
Ch. 9 (27.065)	32.800	6.190	5.735
Ch.10 (27.075)	"	6.180	5.725
Ch.11 (27.085)	"	6.170	5.715
Ch.12 (27.105)	"	6.150	5.695
Ch.13 (27.115)	32.850	6.190	5.735
Ch.14 (27.125)	"	6.180	5.725
Ch.15 (27.135)	"	6.170	5.715
Ch.16 (27.155)	"	6.150	5.695
Ch.17 (27.165)	32.900	6.190	5.735
Ch.18 (27.175)	"	6.180	5.725
Ch.19 (27.185)	"	6.170	5.715
Ch.20 (27.205)	"	6.150	5.695
Ch.21 (27.215)	32.950	6.190	5.735
Ch.22 (27.225)	"	6.180	5.725
Ch.23 (27.255)	"	6.150	5.695

Synthesis: "A" - "C" = direct TX carrier frequency;
"A" - "B" = RX frequency (offset lower by 455 KHz)

Example: For Ch.1, 32.700 MHz - 5.735 MHz = 26.965 MHz, the on-channel TX frequency. During RX, the 6.190 MHz crystal is used, which is exactly 455 KHz higher than 5.735 MHz. This produces the second IF for the receiver. This particular scheme has no fixed high IF since it must pass a *band* of frequencies from 5.735 MHz to 5.695 MHz; only the 455 KHz second IF is constant.

Figure 9—The frequency synthesis scheme of the Messenger 123.

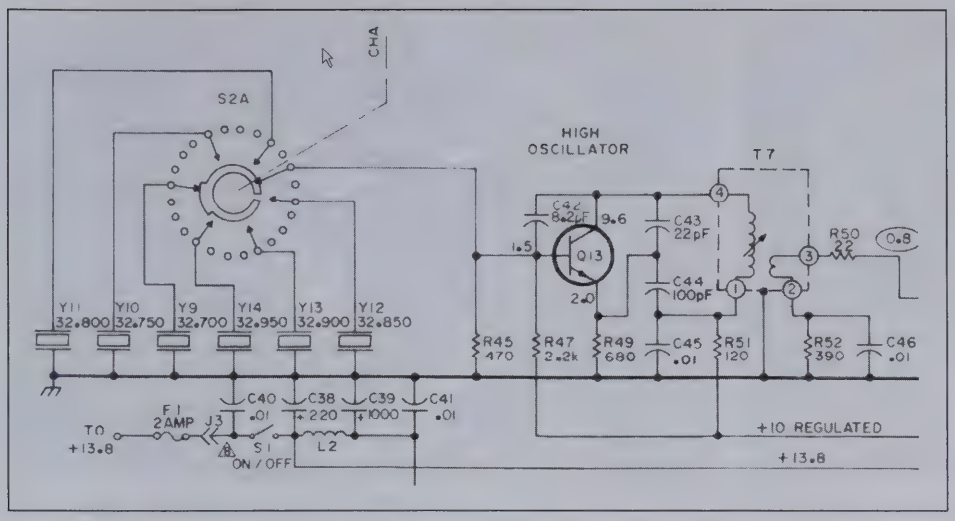

Figure 10—Schematic of the high oscillator. Changing any one of the crystals will move 4 channels from the CB range to 29 MHz.

123A which I converted, the 122, 122A 123, 123SJ, 123B, 223 and the 250 all share the same synthesis scheme. It's likely that many other Johnson radios also fall into this category. I only have experience with the 123A and the 250 (base station model). Prices go from $1 to maybe $30 per radio, which includes a microphone.

The first step is to connect the radio to a fused 12 VDC supply and connect an antenna to confirm that the radio is fully functional. You will likely hear chatter on all of the channels during daylight hours. Check the volume and squelch pots and clean them if they are noisy. There should be lamps for the channel dial and the S meter. Two side screws and a pair of flathead top and bottom screws are removed to release the cabinet. The synthesis crystals are all mounted to the channel selector rotary switch. The crystals we are interested in are on the rear deck: Y9 through Y14.

I chose to use the Y9 position as the four 10M channels would now be on dial channels 1 through 4; easy to remember. It was not necessary to remove Y9. I just cut the lead from the crystal that normally goes to the next wafer section forward.

There are two spare crystal pair holes in the rear wafer between Y9 and Y14. The outer sets of holes all the way around the switch are ground. I installed the Chinese crystal with one lead in the outer ground pads and the other lead sticks out away from the wafer and is attached to the wire lead I had cut from Y9. See Figure 11.

A frequency counter or general coverage receiver will be useful to check the crystal for oscillation and frequency. Attach a counter to the collector of Q13 with a high impedance probe. There should be enough signal there for it to lock onto. All of the crystals I tried resonated off frequency. Initially, I installed a netting trimmer capacitor in series with the hot crystal lead. Once I had the cap adjusted for 34.735 MHz I measured it. A 10 pF NP0/COG capacitor appears to bring the crystals within 500 Hz or so of center; fine for AM work. If the crystal is not oscillating, mark the present location of the slug in T7 (Figure 12) and turn it counterclockwise. The oscillator should take off. The 123 manual (Note 2) has full alignment instructions.

Once you have the high oscillator working, set the channel selector to CH1 (29.00 MHz) and use a signal generator or an attenuated output from your transceiver to loosely couple a low level signal into the antenna connector. Peak T1 and T2 for maximum signal.

After the receive is working at 29 MHz you can touch up the RX IF stages: T4 and T3. Unless a "golden screwdriver" has been in the rig, these should not need adjusting. Each time the injected signal gets stronger, reduce its level so that the signal stays just above the noise. Avoid adjusting the crystal/ceramic filter Z1 unless the audio is obviously pinched.

Once you have the receiver working, it's time to tackle the transmitter section. Install a 5 watt or greater termination onto the antenna socket. Initially the TX power will be so low as to be undetectable on a wattmeter. You can follow the transmitter

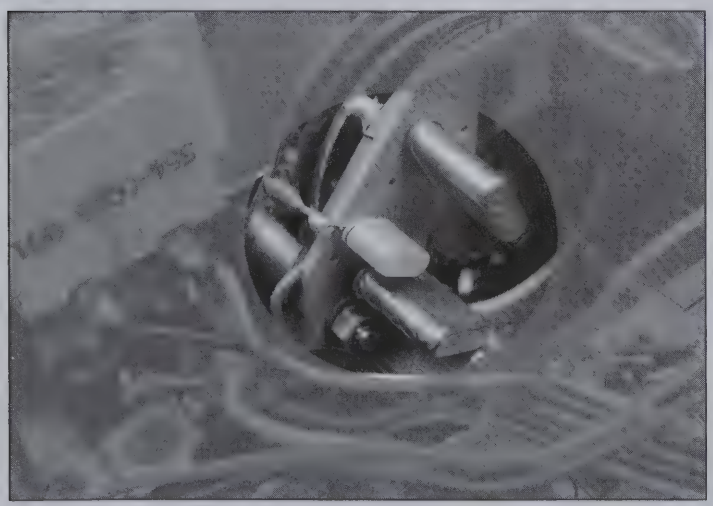

Figure 11—The synthesis crystals on the channel selector switch. The added crystal, the small one next to Y9, has a capacitor in series with the lead to tweak the frequency.

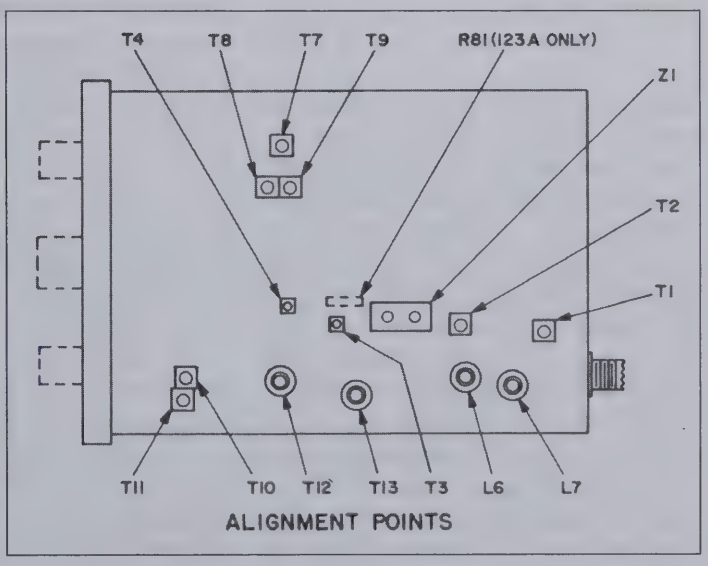

Figure 12—Location of circuit adjustments.

tune up instructions in the service manual, but if you have a high frequency scope or a general coverage receiver you can get close by loosely coupling the receiver around Q15 or Q16 and tuning T10/T11 for maximum signal on 29.00 MHz. A scope coupled similarly will yield more accurate peaking.

From there, proceed to T12, T13, L6 and L7 in that order. If you are monitoring the current drain from your 12 V supply, you should see the current drain increasing. Go back and re-peak the entire TX chain. Finally, readjust L6 for maximum power out at minimum current drain from your power supply. I have seen anywhere from 2 to 3.5 watts from the 123A series.

From memory, I recall that originally these rigs had a red spade lug socket on the rear panel for the power connection. I replaced that with a standard coaxial power connector.

Conclusion

Converting these radios has been a fun project for our group. Occasionally a purchased rig has some bad components and it may then serve as a donor for other rigs. I have worked Italy and other European stations barefoot but also have a small solid state amp that gives me 50W out on AM. I hope to work you on 29 MHz AM.

Note 1: eBay supplier URL: http://www.ebay.com/itm/HOBBYDREAM-UM-5-35-190Mhz-Ch79-FM-Receiver-Mini-Crystal-1pc/140729277786

Note 2: http://www.cbtricks.com/radios/ef_johnson/messenger_122_123a/index.htm

—de W4OP

Simple Adjustable Tracking Power Supply

From Bryant Julstrom, KCØZNG—

The usual experimenter's bench power supply provides an adjustable positive voltage of up to 25V at up to 1A of current. This suffices for many circuits and projects, but others require positive and negative voltages of equal magnitude. Op-amps, for example, often require ±15V.

Fixed matched voltages are easy to provide with a pair of three-terminal regulators, one positive and one negative. A more flexible solution imitates the adjustable positive supply: a tracking power supply provides an adjustable positive voltage and an equal but negative voltage; the negative voltage tracks the positive one.

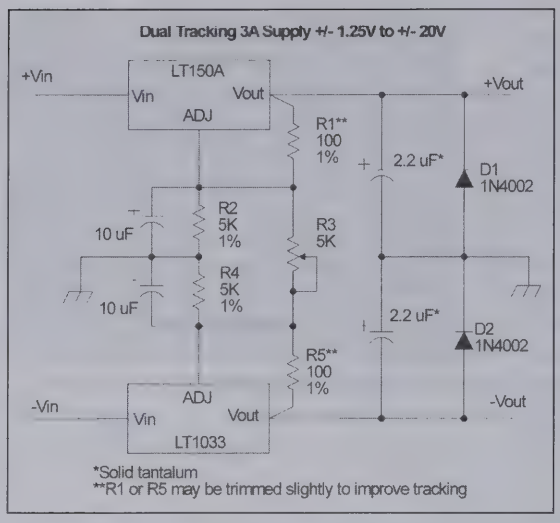

Figure 13—From the datasheet of the LT1033, a tracking regulator circuit that uses positive and negative regulators.

A simple way to obtain adjustable symmetric voltages extends the two-regulator fixed-voltage solution with adjustable regulators and a two-section pot, which adjusts the positive and negative voltages simultaneously. This is simple, but tracking accuracy depends on matching the resistances associated with the two regulators, including the pot's two sections. A related circuit uses an op-amp to invert the control voltage of a positive regulator to control a negative one or a pass transistor. This is elegant, but it limits the supply's voltage to slightly less than the op-amp's maximum input voltage, usually 18V. Manufacturers have produced a number of integrated circuits designed to control tracking power supplies. W1KLK described a supply that used the SG1301 back in 1973 (see Reference). A similar chip is the RC4194. These and others like them have become unobtainium in recent years.

The Circuit

The datasheet for the LT1033, a negative three-terminal regulator from Linear Technology, presents another option: a tracking regulator circuit in which a single pot sets the output voltages of a positive and a negative regulator. Figure 13, reproduced from the datasheet, shows the circuit. It isn't necessary to use the regulators shown; I implemented the circuit using two old standbys, an LM317 positive regulator and an LM337 negative regulator, both in TO-220 packages. Note that the input voltages of the circuit are limited only by the maximum inputs of the two regulators, now ±40V.

Input to the tracking regulator is a pair of voltages and a common line between them. This requires a power transformer with a center-tapped secondary. The beefiest transformer in my junk box provided only 26 VCT, and input to the regulator of ±13V was too low. One solution uses two identical transformers with their primary windings in parallel and their secondaries in series.

I chose to use the one transformer and back-to-back half-wave voltage doublers, one on either side of the secondary winding's center tap, to provide about ±26V to the tracking regulator. This halves the cur-

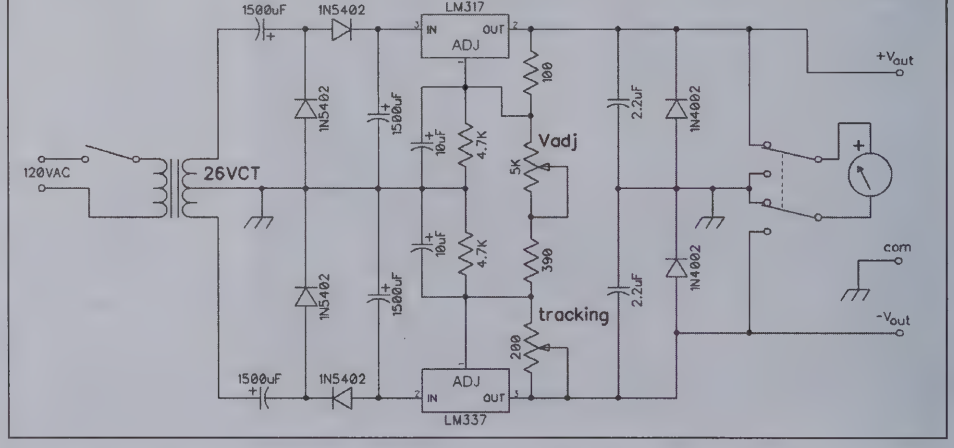

Figure 14—A tracking power supply using familiar parts, based on the regulator circuit in Figure 13.

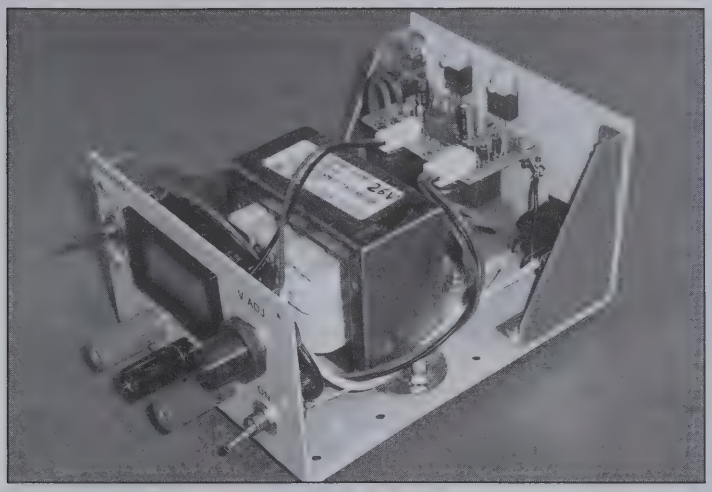

Figure 15—Interior view of the tracking power supply.

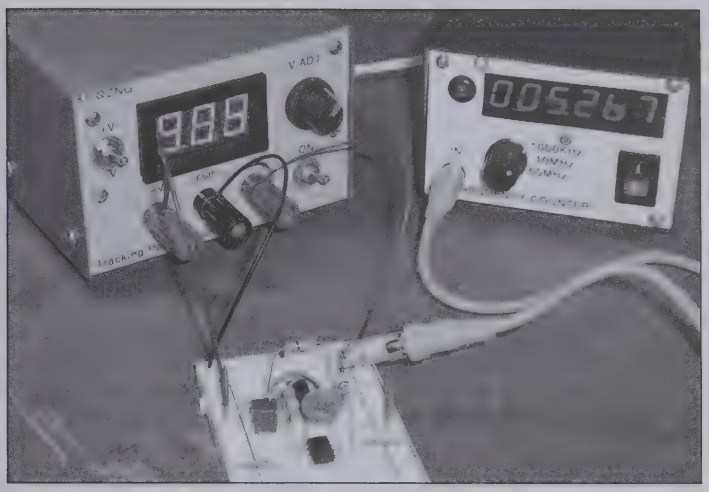

Figure 16—The tracking power supply in use.

rent that can be drawn from the transformer, but it is rated at 2A, and 1A in each leg of the supply is sufficient for a wide range of projects. A voltmeter can be switched across either of the supply's outputs.

Figure 14 shows the circuit of the entire tracking power supply. I used 1N5402s in the voltage doublers because I had a bunch of them. As in Figure 13, the two 2.2 µF capacitors should be solid tantalum. The regulator departs from the circuit in the datasheet in two places. First, to adjust tracking, one of the two 100 ohm resistors is replaced with a 200 ohm trimpot, following a suggestion in the datasheet. Second, a 330 ohm resistor sets the regulator's minimum outputs at about ±3.6V, for reasons that will be clear in a moment. The schematic was developed using the freeware version of DipTrace™ and edited with Microsoft Paint.

Space on my bench is limited, so I wanted the supply to be no larger than necessary. Its front panel holds three binding posts, two miniature toggle switches, the voltage-adjustment pot and its knob, and a voltmeter. The meter is a three-digit LED unit from Marlin P. Jones (www.mpja.com; 30217 ME with blue digits, also available in green and red). It is powered by the voltage it measures, as long as that voltage is at least 3.6V (thus the 330 ohm resistor mentioned above).

Inside the enclosure are the transformer and two circuit boards: the two voltage doublers occupy one and the tracking regulator the other. The LM317 and LM337 are mounted at the edge of the regulator board and attached to the back panel, which then serves as a heat sink, with mica insulators, nylon bolts, and a smear of heat sink compound,. The panel also holds a snap-in IEC three-wire line connector. All the parts came from my junk box except the digital meter and the four 1500µF electrolytic capacitors in the voltage doublers.

The enclosure was bent up from two pieces of sheet aluminum, with brackets at each corner of the bottom half to stiffen the front and back panels and provide attachments for the top, which is held on with sheet metal screws. The enclosure is painted in two shades of gray, and labeled with black-on-clear tape from a Brother™ label-maker. The unit rests on four press-on rubber feet.

Figure 15 shows the unit with the top off and before the last bracket was installed. The regulator board is visible on the back panel. The doubler board is below it, mostly hidden behind the transformer. It's tight in there; cutouts on the brackets' tabs accommodate the line connector, the transformer's mounting tabs, and the switches and pot on the front panel.

Adjustment and Performance

The only adjustment in the supply is the tracking trimpot, which must be set so that the two voltages track each other accurately. This is touchy, but the two voltages can be made to match within 0.1V throughout the supply's range. The completed supply provides closely matched positive and negative voltages from ±3.6V to about ±23V, and a maximum current of 1A in each leg. Figure 16 shows the unit in use.

The tracking adjustment and the front-panel voltage adjustment are delicate. In both cases, multi-turn pots would be much easier to set. The tracking trimpot could be replaced with a series resistor and a smaller-value pot. An analog meter or a digital meter with a separate power supply would allow smaller output voltages. One could augment the supply's measurements with current metering or with simultaneous measurements in both legs, though more meters will require a larger enclosure. A higher-voltage transformer or, as mentioned, two transformers would allow output voltages of greater magnitude. However, as constructed, I've found this supply a handy addition to my bench.

[WA8MCQ Note—I added Figure 17 which shows the connections of some commonly used 3 terminal regulators. I got myself in trouble a time or two over the years when I forgot that the connections of positive and negative regulators are different.]

Reference:

W1KLK: "A Dual-Polarity IC Regulator," Technical Topics, *QST*, February, 1973, p.49.

—de KCØZNG

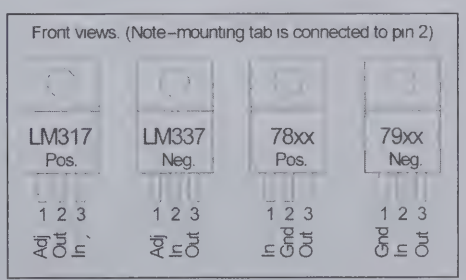

Figure 17—Pin connections of various regulators.

SMD Soldering Aid

Working with surface mount components can be challenging to many due to the small size, and some people have devised devices to hold the components in place during soldering. Those range from very simple to rather complex, and a few have appeared here over the years. The February 2014 issue of the online 4SQRP club's Ozark QRP Banner contained this article about one from Bill Dekle, KV6Z. (All back issues can be found at http://www.4sqrp.com/TheBanner.php)

I recently ordered a kit that consisted of a circuit board and about a dozen surface mount components. When I received the kit in the mail and opened the package, I found a tiny plastic bag inside that contained the entire kit. The board was not much larger than a postage stamp and my dog had fleas that were bigger than some of the components. I've had a little experience with SMD, but nothing this tiny. This was going to be trouble.

I realized that my usual soldering techniques just wouldn't work for such tiny surface mount parts so I put the kit away until I could come up with some way to make my soldering life easier. I was aware of the technique of tinning one end of an SMD device (or pad) and then holding it down using one hand while tack-soldering the tinned end with the other. I also read that it's best just to heat the pad and let the solder flow to the device. Because I don't have a circuit board vise, I needed a way to hold both the part and the circuit board firmly during soldering. I felt that I could come up with something that would do the job using low cost, commonly available parts and easy assembly methods. After some consideration, the device shown in Figure 18 emerged.

Bill of Materials:

Item	Qty	Size, comments
Wooden base	1	5" x 14 1/2" x 3/4"; poplar
Shelf liner material	2	3" x 4 3/4" (shown in Figure 20)
Shelf liner material	1	4" x 4"; used to cushion the PCB
Hinge post	2	3 1/2" x 1 1/2" x ½"; poplar
PVC tube, Sch. 40, 1/2"	1	8"
PVC tube, Sch. 40, 1/2"	2	1.7"
PVC tee, Sch. 40, 1/2"	1	
PVC end caps, Sch. 40, 1/2"	3	
Wood screws, #6, 1 1/4"	4	Fine Phillips head drywall screws
Hold-down point (see text)	1	3/16" dia X 3 3/16" (2 shown in photo)
Cup hook, 5/8"	2	Brass; anything will work
Rubber band	1	Any
Rubber dot	1	5/16" dia X 0.078", cut from old rubber boot

Table 1—List of materials used to build the SMD hold-down device.

The rubber band supplies downward force on the pivot arm which allows the point to firmly hold an SMD device on the circuit board and also holds the circuit board to the work surface.

Since there is a great deal of latitude in the dimensions and the materials that will accomplish the same objective I won't describe a step-by-step construction procedure, but rather just describe the parts I settled on along with some assembly comments that will allow you to reproduce this device or one that is functionally similar. Figure 19 shows the parts ready for assembly. Table 1 is the bill of materials.

I made the first hold down point from an old aluminum tent peg and then read somewhere that the use of a heatsink during soldering is undesirable. (I read that a few days after I read that it WAS desirable to use a heat sink.) Although I'm not convinced it makes much difference, I used a hardwood hold down point on my first SMD board. Both points were tapered over a length of 3/8-in. to a flat point of 0.02" diameter. I applied a coating of CA (cyanoacrylate glue) to the tip of the hardwood point for added durability.

The circular red and black marks near the left end of the board (along with corresponding marks on the bottom of the hinge posts that can't be seen in the photo) were made with ink markers to insure consistent orientation of the posts during repeated assembly and disassembly. The cup hook location marks can be seen in the photo and they are 3" and 5 1/2" from the left end of the board. The board used was heavy enough to stay put when the pivot arm was lifted during use.

The purpose of the rubber dot is to cushion the point/board contact area when the device is not in use. (Figure 18 shows the point resting on it.) This will prevent damage to the point (especially when using

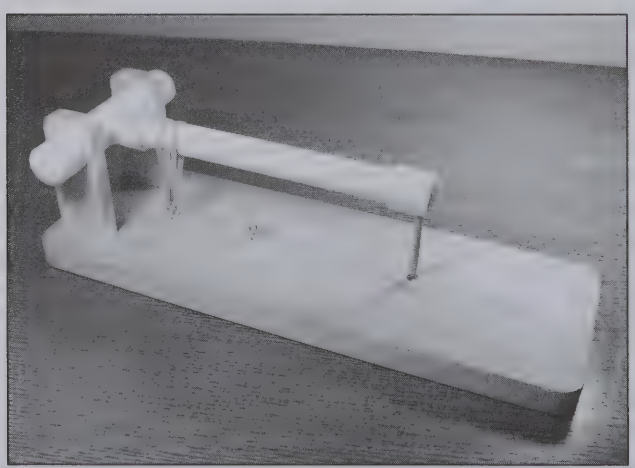

Figure 18—SMD soldering aid.

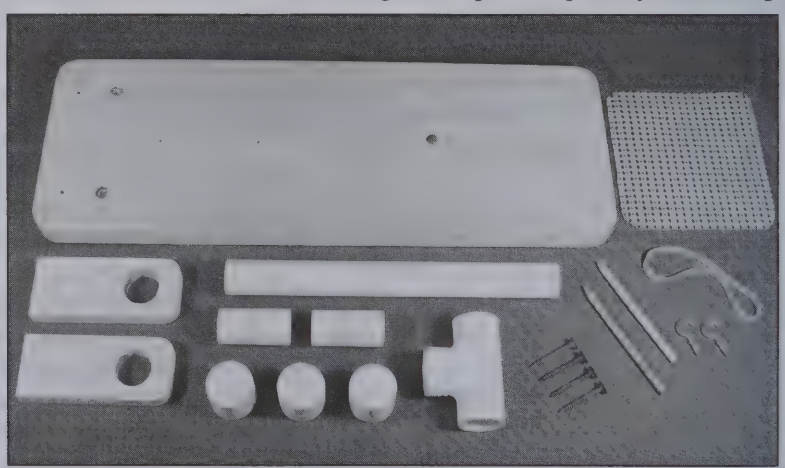

Figure 19—The parts to build the device.

the wooden one) and also prevents damage to the board for either the wooden or aluminum point. It was inlaid in the base after assembly to insure alignment with the point.

The length of the 2 short pieces of PVC tubing was determined by measuring the plunge depth of the tubing into the tee and end cap and adding the thickness of the wood hinge post material. In my case, I got 0.683 in. depth for the tee, 0.540 in. depth for the cap, and 0.456 in. for the wood thickness (after sanding) for a total length of 1.679 in. That length provided a good friction fit for the pivot arm assembly and result in minimal side-to-side 'play'. All the PVC parts are assembled using friction fit only. Due to the internal taper of the tee and end caps, friction is sufficient and allows adjustment after assembly.

Not shown in Figure 19 are the two rubber pads made from synthetic rubber shelf liner that were glued to the bottom of the board using spray adhesive. They keep the board from slipping during use and are shown in Figure 20. One pad has material cut away in 4 places to allow access to the countersunk hinge post screw heads. The 4" x 4" pad shown in Figure 19 is used on the top side to cushion the PCB and was not glued to the base.

There are 15 holes to drill:

- 4 clearance holes in the base board for the hinge post screws.
- 4 matching pilot holes on the bottom of the hinge posts.
- 2 pilot holes for the cup hooks.
- 1 shallow hole to inlay the rubber dot.
- 2 clearance holes in the hinge posts for the PVC tube.
- 1 clearance hole in the end cap for the hold-down point.
- 1 shallow hole in the end cap for the point seat.

For the large clearance holes in the hinge posts, I used a 13/16-in. spade drill and then filed and sanded until I was satisfied I had the smallest hole possible that offered minimal friction to the PVC pivot arm. I'm not sure this is the best way. If I were to build another one, I think I might just drill 7/8 in. holes and call it a day. The center is located so that the pivot arm is approximately horizontal when the point makes contact with the base. This distance can be found by installing the point into the end cap and measuring the distance from the center of the end cap opening to the end of the point.

Figure 20—Underside of the base. The two pads keep it from sliding around.

Figure 21—Both hold-down points and end cap, near the inlaid rubber dot.

Figure 22—Hold-down point mounted in the end cap. Only one hole goes all the way through.

Alignment of the hinge posts is the only really critical part of construction and will test your woodworking skills. Make sure the posts are vertical and parallel to each other. Use the PVC tee as a spacer to determine the post separation when you mark the hole locations. You can sand the inside surface of the posts if they end up too close. The point assembly is shown in Figures 21 and 22.

For 3/16" diameter dowel material, a #13 drill (0.185" dia) results in a good friction fit for the hold down point. Keep the diametrically opposed holes as far from the open end of the PVC cap as you can so the pivot arm tube does not contact the point material when assembled. The hole at the top of the point is only drilled to a depth of about half the wall thickness and does not go all the way through.

After all the holes are drilled, secure the hinge posts to the board and press all the PVC parts together. Get the end caps as close to the posts as possible without causing any binding and then rotate the point assembly until the hold down point is perpendicular to the board.

There are an endless number of ways to arrange a rubber band to produce the desired pressure on the part. You'll have to decide how much pressure you want. The exact configuration will depend on that decision along with the dimensions of the rubber band you use. For the one I had on hand, I settled on the configuration shown in Figure 18. For that configuration and a point tip diameter of 0.02 in., a force of 17.2 oz. was produced on the part and this felt about right to me. This force resulted in a normal stress value on the part of about 900 lb/sq inch. (Maximum normal stress values for North American hardwoods vary from about 5000 psi to 9000 psi.)

The same rubber band in the second hook position resulted in about 3500 lb/sq inch. Don't let a configuration like that come down on your finger. Always keep your fingers clear of the point contact area and don't lift the pivot arm any more than

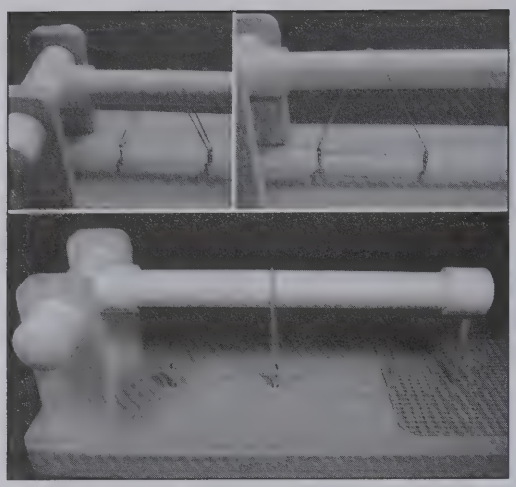

Figure 23—Various rubber band configurations. You may have other ideas.

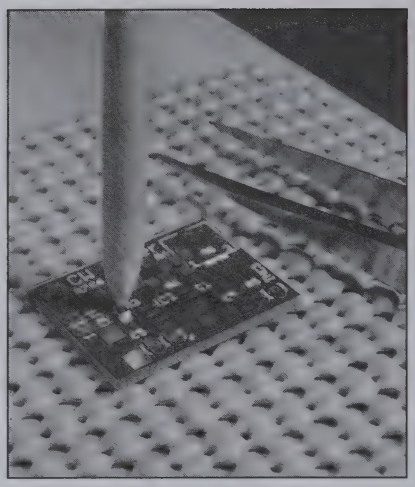

Figure 24—The device in action on an audio filter PC board.

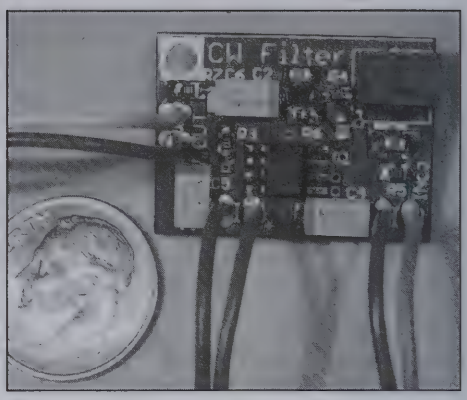

Figure 25—The finished SMT component PC board.

necessary to clear the circuit board and the part to be soldered. A few alternate configurations for rubber bands of varying sizes are shown in Figure 23.

Figure 24 shows the device holding the first resistor firmly to the board, ready to be soldered and Figure 25 is the finished circuit board.

Some of my solder joints are a bit globby, but that's because the diameter of the solder I used was too large. I may use solder wick later to remove the excess. The SMD soldering aid, however, worked exactly as I had intended and actually exceeded my expectations. What started out as a design exercise resulted in a very useful tool that I will use to assemble SMD circuits with confidence. And rest assured, it was much easier to build the tool than it was to describe it.

Oh—and the circuit board (a tunable audio CW filter from www.hamshop.cz) worked the first time.

[WA8MCQ comments: A final safety note; unlike some SMD soldering aids, this is basically a pointy thing under tension, and has potential for puncturing skin if you're not careful. Don't lift it up too high and don't let it go suddenly. Use the minimum necessary tension on the rubber bands. It could also damage a board or component.]

—de KV6Z

Carrying Strap for the FT-817

From Jim Fitton, W1FMR—

Here's a fairly quick way to get a carrying strap on a used Yaesu FT-817 that did not come with the original carrying clips or strap. This idea worked out pretty well and didn't cost the $27 advertised on that famous online auction site for the clips alone.

Using a hacksaw, two sections were cut from a length of half inch aluminum angle stock from Home Depot and drilled as shown in Figure 26. The original mounting screws were used and a short length of cord formed an attachment loop for a laptop computer carrying case strap (Figure 27). While this does not look as slick as the original equipment, it is easy to fabricate, inexpensive and serves the purpose well.

—de W1FMR

A Directional Wattmeter

From Merton Nellis, WØUFO—

This little directional wattmeter is one of my favorite radio accessories because it is so simple, passive and useful. I use it to know that a good portion of my transmitter power is going to the antenna. When adjusting an antenna matching circuit it will tell me when I have reduced the reflected power to a minimum. It is a passive circuit that takes a small fraction of the transmitter power to operate, so I leave it in line at all times to assure me that my power is going out with minimum reflec-

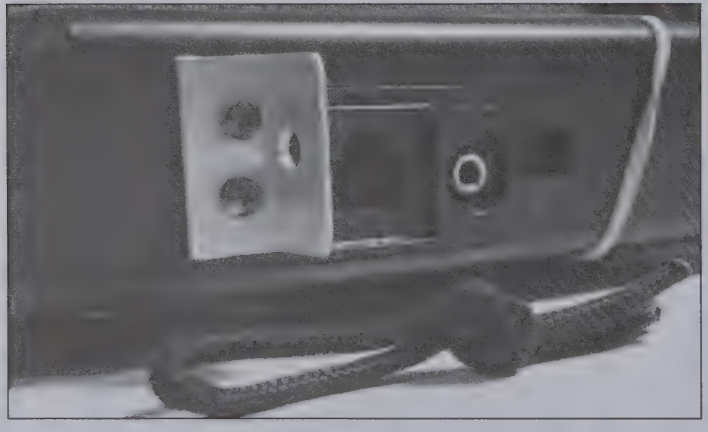

Figure 26—Cut brackets from aluminum angle stock and mount to the sides of the radio with existing screws. Knot 2 loops of cord as shown.

Figure 27—A laptop carrying strap clips onto the loop. Other types of clips and straps will work, as well.

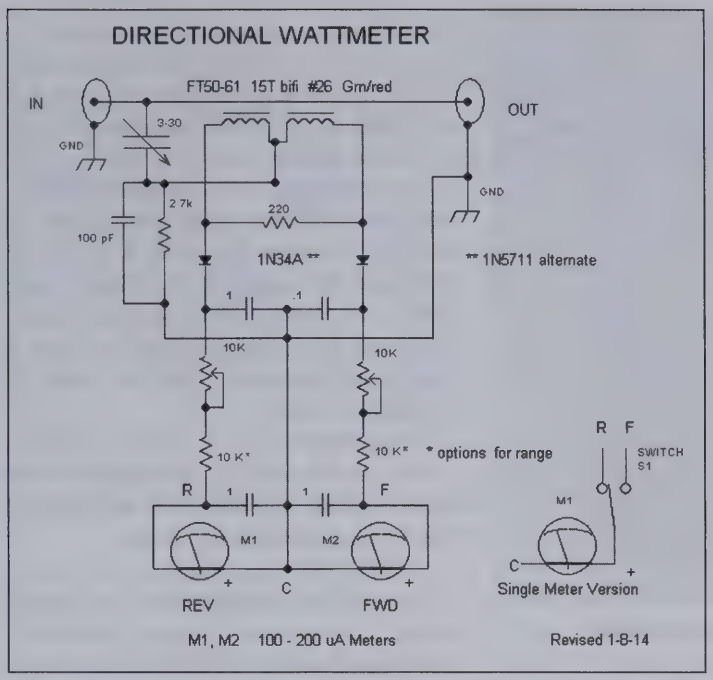

Figure 28—Schematic of the directional wattmeter.

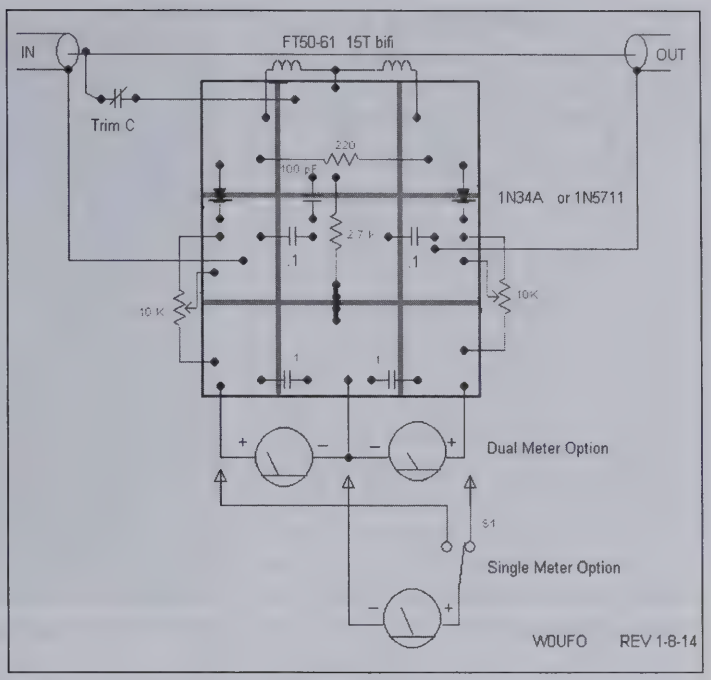

Figure 30—Layout on the board.

tion. It is small, light and relatively rugged so goes into the field with ease.

I use the circuit shown in Figure 28. It is an adaptation of the circuit I first saw in Doug De Maw's book *Practical RF Design Manual*. I first used vector board for circuit construction but lately I construct the circuit on a piece of printed circuit board about 1 1/2" square (Figure 29) by creating islands of copper in a 3x3 square pattern using my bandsaw that has an 18 tooth per inch blade. (The technique is discussed in a separate article following this one.) The circuit is formed on the board as shown in Figure 30, and Figure 31 shows the assembly sequence.

Figure 29—Pads are cut onto a small piece of unetched PCB material about 1-1/2" square.

After I constructed the board I assembled it into an LMB #00 box. But first, the BNC connectors, the meter, and the switch are mounted to the box. Finding and choosing a meter was a problem. I finally found one at Dan's Small Parts and kits. It is a 0-200 uA movement with suitable VSWR scales markings. I would rather have had a cross needle meter with a 0-100 uA movement. MFJ has such a meter but more expensive than I wanted. Figure 32 shows how I connected the board to finish the circuit and Figure 33 is the completed unit.

I test the finished circuit by connecting a 50 ohm dummy load to the output BNC and a 5W transmitter to the input. When I key the transmitter, the meter will indicate nicely if the connection is for forward power and only slightly if for reverse. I then adjusted the trimmer capacitor to get minimum in the reverse direction. When

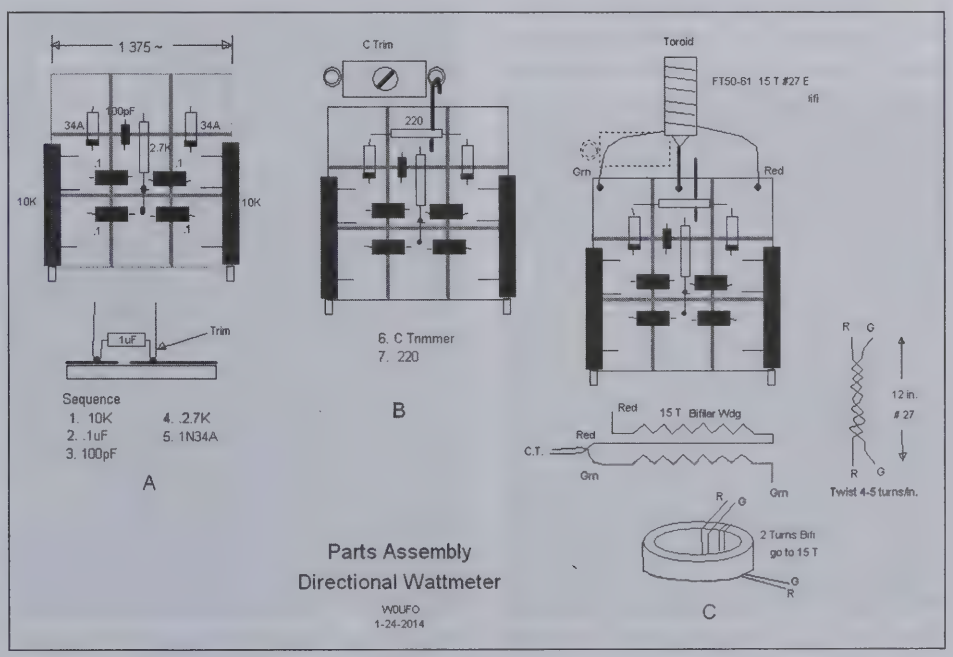

Figure 31—Assembly sequence.

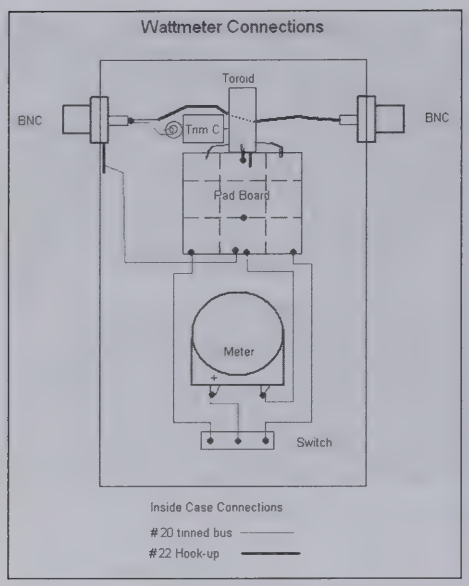

Figure 32—Connections to the wattmeter board.

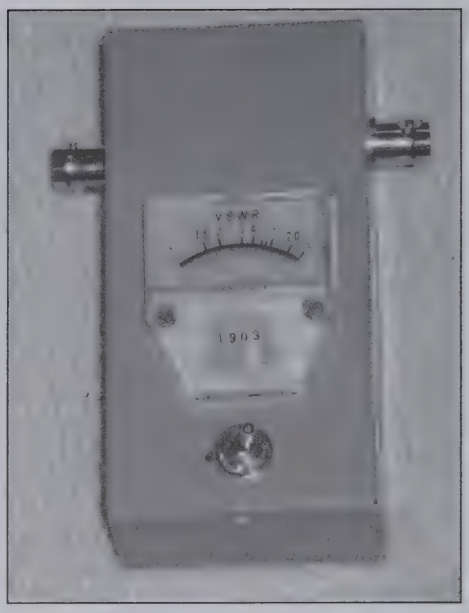

Figure 33—The completed unit.

watching the forward indication, adjust the forward trimmer potentiometer to read the correct power. The power into the load can be measured either by a peak to peak oscilloscope reading or by a peak reading RF detector. By scope, power on a 50 ohm load equals Vp-p squared divided by 400, or by detector Vp squared divided by 100.

To adjust the reverse to the same sensitivity, swap the transmitter and load connections so that the reverse connection now becomes the forward and adjust the reverse potentiometer to read the same as the forward value.

I mainly use this meter to adjust antenna matching for minimum reverse power and as an indicator that I have more power going forward to the antenna than reverse. The accuracy does not have to be high but the relation between forward and reverse is most useful.

—de WØUFO

Cutting Pads in PCB Material

Figure 29 above shows a quick and dirty board that WØUFO used to build his directional wattmeter. Many people have used this basic approach for years, using a variety of methods to isolate the pads, such as Xacto blades, Dremel tools, ceramic tile cutters, etc. Mert uses a bandsaw. The following is based on some e-mails we swapped.

Mert said, "If you have a band saw with fine teeth, like 18 teeth per inch, you can make small PC boards using it to cut islands for use in mounting parts. The saw cut is fine enough so that larger surface mount parts can bridge across the grooves cut by the blade. Figure 34 shows a board against the blade. In use, the board is held gently to the blade to cut through the copper but not too deep, which can weaken the board. I have built several circuits using this method. I got the band saw blade from Amazon.com, and use it for cutting thin aluminum, plastic, and PC Boards.

"I just hold the board up against the blade by hand so that I can feel the contact and rock it a bit to get a full length cut without going too deep. I made about ten boards for the wattmeters that our radio club built and did it by hand. I guess if I was doing this a lot I might figure out a jig to hold the boards."

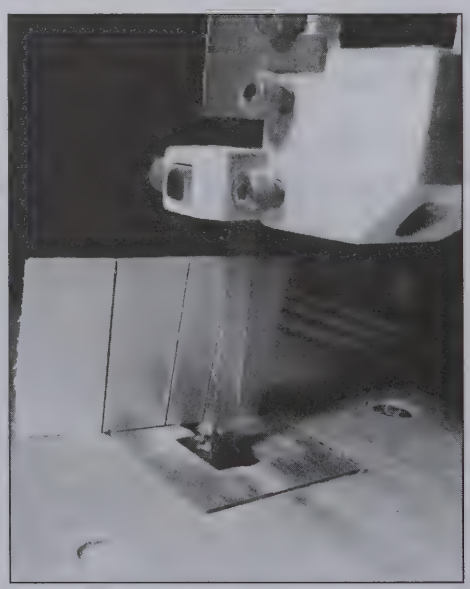

Figure 34—Cutting isolated pads with a bandsaw. (The cut on the left went too deep.)

Mert said that the bandsaw blade is made by PowerTec, 3/8" wide, with 18 teeth per inch. He measured it at 0.025" thick and guessed that it probably cuts 0.03" wide. I asked him what he did to debur the board. He said that he uses a small three cornered file and drags it through the cuts.

Figure 34 also shows what can happen if you go too far. He said that he went much too deep on the left cut and that the board was actually floppy there.

As is always the case, be careful when using a bandsaw since it can easily cause injury if your hands contact the blade. When doing something like this you might want to try taping the board to a block of wood before cutting.

General Purpose Crystal Oscillator/Buffer

From Harold Smith, KE6TI—

I built up a quick, simple general purpose crystal oscillator and buffer, shown in Figure 35. Crystal oscillators are common, but the nice thing about this one is the purity of its output. I've used it with crystals from 1.8 to 28.5 MHz, and all harmonics are down 35 dB or more, with no filtering. Output into 50 ohms varies from about +10 to about +20 dBm, depending on the crystal activity and frequency.

Using this circuit to drive a high impedance nullifies the clean output. Instead, you get a series of large, positive-going spikes. with peaks of several volts. But into 50 ohm loads the output is very clean.

I don't claim this circuit originated with me. I don't remember where I found it, but taking the output of the oscillator off a small impedance in series with the crystal is why the output is so clean.

The transformer in my version is 9 bifilar turns on a quarter-inch diameter ferrite toroid, probably type 43 or similar. The crystal socket is a cut-down IC socket. The output transistor, a TN2219A, is just a PN2222A in a higher-dissipation package. A 2222 should also work, but would probably want a heatsink. It's dissipating close to half a watt.

—de KE6TI

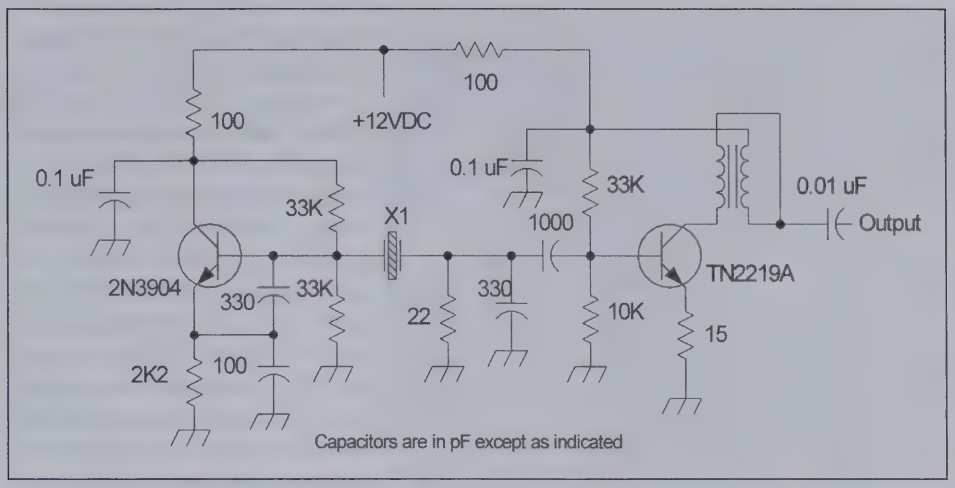

Figure 35—Schematic of the oscillator and buffer.

Shorting Function for the SMD Adapter

In the Fall 2013 issue I described an adapter to measure surface mount devices (SMD) on the AADE LCII meter. Bob Nelson, K6KL, suggested that I do a layout with ExpressPCB to make it reproducible, and offered to pay for a set of prototypes. Figure 36 shows the result. (This is a double sided board with plated through vias everywhere, so no wires or jumpers are needed to short the top and bottom of the board.)

This differs somewhat from my homebrew device. On that one, the side was used for the shorting bar function, but this one uses the opposite end of the board. To short the binding posts and zero the meter before measuring inductors, the adapter is flipped around to the other end, the meter is zeroed, then the adapter is flipped back.

I kept one and sent the remaining 9 prototypes to various people to get their impressions and comments. Several mentioned it being cumbersome to reverse the adapter to zero it for measuring inductors and flip it around again to do the measurements. I originally didn't think it would be that big a deal since I suspect the majority of AADE users will not use SMD inductors to any great extent. (For one thing, the Q is usually fairly low compared to the same inductance on a powdered iron toroid.)

However, some folks might like to keep the SMD adapter permanently mounted, and use leads or adapters plugged into the binding posts for testing leaded parts and/or add SIP sockets for plugging in leaded components with relatively long leads. Now the adapter has to be turned around to zero for all inductors, not just SMD, and I decided that it is an issue after all.

Steve Smith, WB6TNL, does all of the above which makes it really handy, being able to test both SMD and leaded parts without having to take the adapter on and off. He considered mounting a normally open pushbutton switch to short across the gap for zeroing but decided against it since it would require pushing two buttons to zero. Instead, he added a SIP header to attach a shorting jumper.

I liked the basic idea and went with a variation of it, shown in Figures 37, 38 and 39. (Although they show it done on a prototype, it is also applicable to the homebrew version.) I took a snap-off strip of 0.100" DIP headers, broke off a piece 4 pins long and soldered it to the edge of the board (Figure 37). I bent the leads in a bit since the space between the two rows is somewhat greater than the thickness of the board. I put it on the edge so it sticks out to the rear and isn't in the way when measuring components, and also doesn't require drilling any holes.

I used a DIP header instead of SIP since that is what was available, but it also makes it stronger since it's soldered on both top and bottom of the board. I made it 4 pins long (8 pins total) for the same reason; more to hold it in place. You could get by with a SIP header with just 2 pins, though, and with care that would probably last forever.

Figure 38 shows the jumper in place, shorting the two sides so the meter can be zeroed for inductors, and Figure 39 shows the short removed for doing measurements.

Steve mentioned the possibility of misplacing his jumper. That's another reason for using so many pins. When not in use,

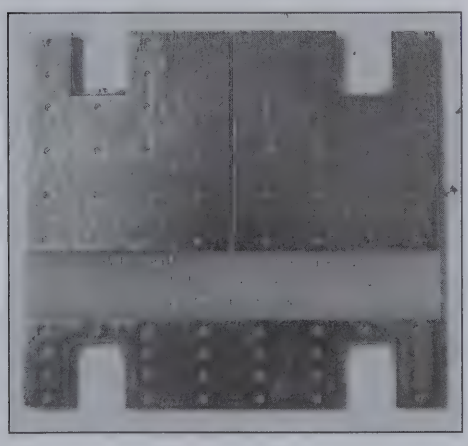

Figure 36—Prototype SMD adapter for the AADE LC meter (or anything else with 1.2" binding post spacing).

Figure 37—A DIP header is soldered on the edge of the adapter.

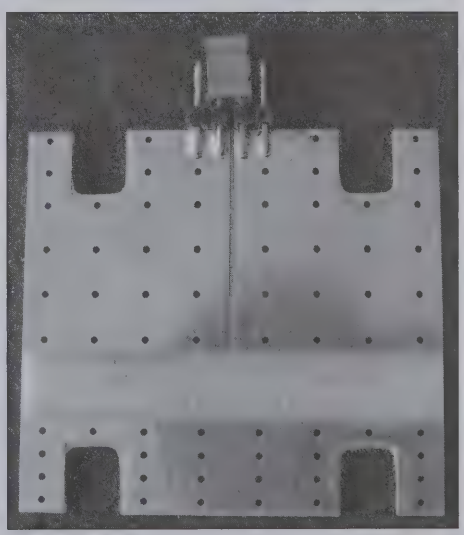

Figure 38—A jumper on the header shorts the sides.

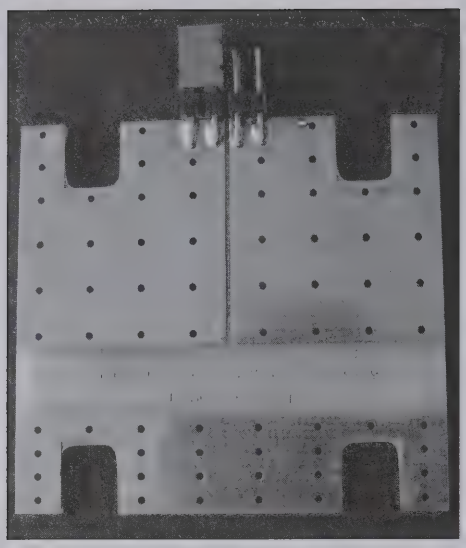

Figure 39—Jumper removed for taking measurements. The extra pins provide a storage area so it doesn't get lost.

Figure 40—Various styles of jumpers for pin-type headers.

the jumper is stored on a couple of pins on one side of the gap (Figure 39). I later added a DIP header to one of my homebrew adapters, just 3 pins long; two on the ground side of the gap, one on the hot side. That allows storage on one side. You could even get by with a DIP header 2 pins long, 4 pins total, one each on the hot and ground sides; just store the jumper vertically instead of horizontally.

The jumper in the photos was from an old hard drive and it failed after moving it around less than two dozen times. It's an open-ended type; after a while the contact assembly broke free of whatever was holding it in place in the plastic and instead of making contact the header pins just pushed it out a bit. It's the second from the right in Figure 40. Note how high the metal strap inside is; it was originally much further down before it went bad. It doesn't fall out and get lost, but it won't make contact either.

A jumper with the end completely closed would be better (4th from the right, the white one). The contact assembly isn't going anywhere; the closed end keeps things inside. An alternative is a style which is called open but which has shoulders covering part of the end (second from left but not too obvious here) and hopefully will keep it inside longer before it eventually breaks free. It's not the best solution but better than completely open.

Most jumpers are small and hard to grasp. The first one wasn't too bad since it's a bit longer than most and sticks out beyond the end of the header pins a little. The problem is that with a DIP header the back side of the jumper is between the rows and covered by the pins on the other row. You can't grasp it easily with your fingers. Figure 41 shows a typical jumper. You could pull it out with long nose pliers; nothing wrong with that, but this is something that will be pulled out frequently so there has to be a better way.

A jumper with a tab or handle on the end is best; that gives something to grab onto and makes it easier to pull it off the header. (That's the tall one on the right in Figure 40.)You might get lucky and find some of these on old circuit boards but will probably have to buy some. I bought a pack of 50 from a domestic seller on eBay; with shipping they cost under 8 cents each and several other sellers have similar prices. You can also find them at Mouser, DigiKey, etc. but they are more expensive. One is DigiKey 952-1855-ND, 41 cents, although others are somewhat cheaper.

Figure 42 shows the far side of one on the header. It extends well beyond the pins and is much easier to pull off. Part of it is still covered by the pins but that doesn't matter now.

Choose your search phrase carefully if you look for these on eBay, or you could end up with several thousand things to wade through, almost all of them not being

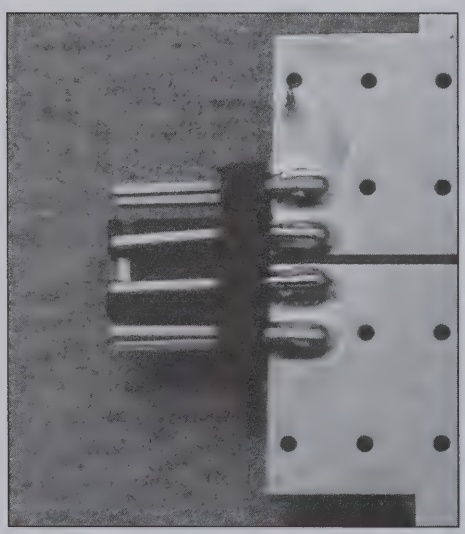

Figure 41—With one side between the rows, a typical jumper is hard to grasp and pull out.

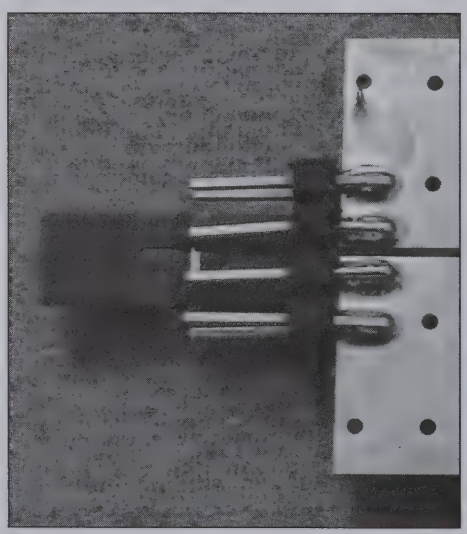

Figure 42—The jumper with tab is easier to pull off. No tools required; just your fingers.

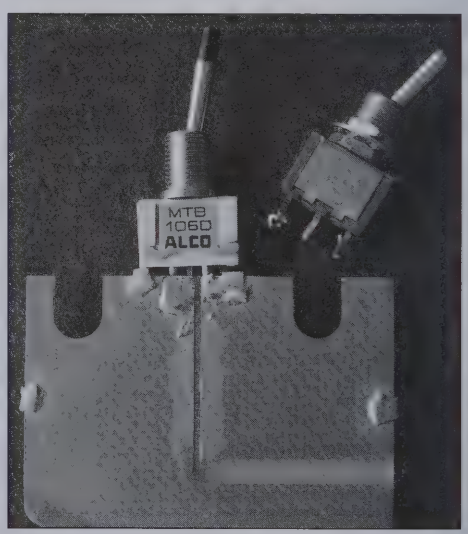

Figure 43—A miniature toggle switch can also be used to short the sides (shown here on the homebrew adapter).

what you want. "Jumper" returns over 278,000 hits, and "shunt" (which these are sometimes called) brings up over 7000. "Header jumper" is much better with around 200. Just about all of them are relevant, but few have the handle. A better phrase that catches more of this type is "jumper handle." There are still a lot of unrelated things, but easy enough to wade through (just a couple hundred).

Be careful to get the correct type, which is 0.100" spacing or 2.54 mm. There are other header spacings, so watch out for this. And check the price carefully. Although I found several that had prices of under ten cents per piece there were some that wanted prices about the same as those in the catalogs, and some wanted a lot more than that.

I tried a miniature toggle switch for shorting as well. I was afraid that it would add significantly more inductance to the zeroing step than a short directly across the gap (addressed later) but with the switch I used it wasn't much different than with the header/jumper. I used a regular on/off toggle switch rather than momentary contact, so only one button has to be held down to zero. (Don't worry about forgetting to flip it back; you'll remember as soon as you measure an inductor and see 0.000 uH.) Like the headers, I mounted it horizontally off the back end of an adapter to keep it out of the way.

Figure 43 shows the switch mounted on one of my homebrew adapters, which is doublesided but has no vias. Instead, it has pieces of used desoldering braid shorting the tops and bottoms. (Some of them are near the switch and not too visible here.)

Both switches shown happen to be SPDT but an SPST (or even DPDT) switch is just as good. I soldered it to the underside to keep the terminals out of the way, but putting it on top would probably have been better mechanically (more support if there is any downward force on it).

I originally used the switch on the right, which was harvested from a scrap something-or-other where it had been exposed to the atmosphere for years. When I closed it for shorting it didn't make good, consistent contact every time. Close it, zero the meter, then open and close a few times and it would not always go all the way back to 0.000 but rather show a variety of values, sometimes ten or more nH, and never a repeatable value. The one on the board was still in the unopened baggy; it had not been exposed to the atmosphere for years like the other one. Even though the date code indicates 1975 it gives good, solid contact every time. (That could change after a while, though.)

When zeroing, the signal path through the switch, or header and jumper, is somewhat longer than a short directly across the gap, so zeroing will be to a value that is slightly higher than "true zero." Think of it as zeroing with a very small inductor instead of a short, which skews measurements a tiny bit. This could be significant in some cases, such as measuring really small SMD inductors, where it could be substantial in relation to the inductor. But as long as you know what the added value is, it can be compensated for when needed. Then again, this might not be worth worrying about since the AADE is not a precision instrument by any means.

I was afraid that the switch would show a much higher inductance (relatively speaking) than the header and jumper. I played around trying to measure that with the AADE, zeroing each adapter with it's own shorting bar then turning it to read the display with the header or switch shorted. Results were somewhat variable due to a variety of factors, so I finally gave up and measured everything on an HP 4342A Q meter. That gave more stable and repeatable results.

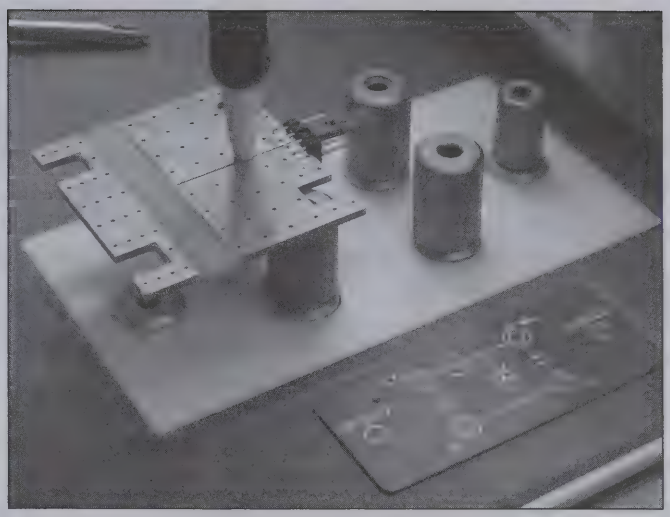

Figure 44—Measuring inductances of the shorting mod on a Q meter. The adapter is held down with a plastic pen.

I set the variable capacitor to the maximum of 470 pF, tuned the oscillator to resonance (monitoring the frequency with a counter) and calculated the inductance. Measuring with the adapter under the binding posts was not practical due to the geometries involved as well as the proximity of the ground stud at the far left (labeled "SHIELD"). I removed that, then placed the adapters on top of the binding posts, held down by a plastic pen as shown in Figure 44. This gets everything well away from the stud and top cover.

The raw inductance values aren't too important, especially since they include the added inductance of the binding posts. The important thing is the difference between the shorting bar side and the switch or header/jumper side. On the fabricated adapter, the header/jumper combo added 3.85 nH to the jumper bar value. That's not worth worrying about too much.

On the homebrew adapter the switch added 5.37 nH to the shorting bar inductance. That is also quite small, and interestingly it turned out to be about the same as using the header and jumper; I had expected the switch to be a lot higher but it was only 40% more. So, at least with a similar switch, it doesn't make too much difference which way you go, whether shorted header pins or a switch.

I have a number of SMD inductors picked up over the years. I played around with measuring them on the adapters and, of course, found that having the shorting mod of either type made the process much easier and more enjoyable than constantly flipping the adapter around to zero the meter. It was well worth the effort.

—de WA8MCQ

Using Male Phone Plugs for Power

In the last issue there was an item about using a male phone plug to supply power to small devices. I later received this note from W4OP—

"I had a comment regarding Figure 37 in the Winter 2014 issue. Using a phone plug for supplying DC power is not good engineering practice, particularly if the external power supply shares a ground with the equipment it is being plugged into. There is voltage on an exposed tip

that can easily short to surrounding metal and what occurs when the phone jack tip is plugged into the equipment is anyone's guess. DC coaxial connectors with internal switches are made for exactly this purpose."

I should probably have included some commentary about it, or, even better, not used it at all. As a general rule I have to agree that it is not a good practice, although it is sometimes done under some circumstances. But when it is, the person should be aware of the issues and know and accept the risks involved.

Something which I highly doubt anyone would ever do, but which makes a good worst case scenario, would be using a 1/4" phone plug as the male connector at the end of a cable coming from a 20 amp DC supply, which has one side connected to ground, feeding power into a piece of equipment with a grounded chassis. Imagine what happens if the tip of the plug touches anything grounded when not plugged in, or when it touches the grounded sleeve of the female jack during insertion.

Presuming that the supply has the other side of the output connected to station or earth ground, the tip could touch just about any grounded metal in the area when not inserted and cause a short, possibly damaging the supply and other things. If the device to be powered is already grounded the tip will briefly short when inserted as it touches the grounded bushing of the jack on approach. And even if the device is not grounded, the tip and sleeve could well be shorted together as they pass through the bushing during insertion.

One reason I didn't give this a second thought is that years ago it was common to see this being done commercially, such as with calculators with rechargeable batteries, etc., and I even had a small computerized chess game that did the same thing except that it was for the power input, not just a charger. All of these used fairly small wall wart supplies, with the output isolated from ground and with limited current capability. They would not draw huge sparks if the tip was shorted, or weld itself onto something or destroy the supply; they could withstand brief overloads. (They would, after all, be briefly shorted when being plugged in.)

All of this, of course, was before the coaxial power plugs came into widespread usage. I doubt that many commercial products use the male phone plugs now due to the drawbacks and since better connectors are available.

The author later indicated that he had built a separate 100 mA 9V power supply to use for his small items, and that it eliminates the problem of a short to ground. And the design is such that it can withstand brief shorts of the output.

Another reason to be careful when using a male phone plug for power is that connectors of that type are obviously used for plugging things into audio output phone jacks. If a power supply output is accidentally plugged into the earphone (or speaker) jack of something, damage to that device could result.

Here's a good, true life example of the dangers of using male connectors to supply power. And this one had potential for far more serious accidents than just shorting the output of a DC supply since it involved the AC power line.

After I had been at one of my many overseas military assignments for a couple of weeks, many years ago, I noticed an equipment rack that had a few duplex outlet boxes on the rear. They were the standard US 3-wire grounded outlets, with conduit run to them. Or most of them, at least.

Someone had added another outlet box to power something that was added later. The proper way to do it would be to run more conduit or at least a good, heavy power cord between them. Unfortunately someone had chosen a very dangerous way of doing it. I noticed that there were two power cords plugged into the outlet; one went to the piece of equipment and the other was plugged into another outlet on the rack. Yes, it was a cord with male plugs on both ends, one of them feeding 110 VAC power into the added outlet box. The potential for damage or injury was considerable. I had no idea how long it had been like that, but probably for some time.

(Not surprisingly, I couldn't get any clear answers from anyone about why this condition existed. And of course if this had been caught during one of the annual inspections by the Quality Control section there would have been a major write-up, and the Safety folks would have had a field day with it.)

Realizing that small phone plugs being used to supply DC power probably happens a lot, hopefully with the person being aware of all of the issues and risks, my official position is that it's not a good idea and should be avoided. (Have I ever done this myself? I respectfully invoke the fifth amendment.)

Just to be safe, I checked DigiKey and Mouser to be sure coaxial power connectors with internal switch and threaded bushing for panel mounting were readily available, and they are. Many are a little over a couple of dollars each, although there are more expensive ones as well. (DigiKey includes "switch" as one of the search options, but Mouser does not, and doesn't seem to even indicate anywhere in the search results whether a given connector has the switch or not. You have to look at the individual data sheet, or go to the catalog page and read the description there. The point for this one goes to DigiKey.)

—de WA8MCQ

The Fine Print

You know the drill—send your info to Severn any way you can get it here (e-mail, snail mail, 3 1/2" floppy, CD, handwritten on a napkin, etc), or tell me where you found something of interest on the Internet.

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Never Move!

Pete Juliano—N6QW radioguy90@hotmail.com

How to Overcome a Small City Lot with No Large Trees

In May of 2013, it was necessary to move to southern California to a residential area where the homes are small and the lots are even smaller. There simply were no 150 foot pine trees in my backyard like I had at my former QTH. I did catch myself saying over and over, "Never Move!" But that does not mean QRP ham radio activities are simply written off as no more.

Thus, I wanted to share with you how I addressed the antenna problem at the new QTH so that perhaps others who are faced with the same situation may benefit from my efforts. I am a process guy and so there had to be some organized process for addressing the situation and this is how I would like to start. Here are the steps I followed:

• Start with an assessment of what is available by looking at the actual physical siting of the house structure on the lot. Using a sheet of engineering type quadrille paper I sketched out my lot which is 60' by 100' and placed the house structure on the sketch. On one side there was a 10 foot setback and on the other a 15 foot setback. From the back of the house to the rear property line was about 32 feet. These were the critical dimensions as there was no way that the XYL would entertain any sort of antenna structure, wires or supports in the front yard. Should I say it again: Never Move! Figure 1 is my hand sketch.

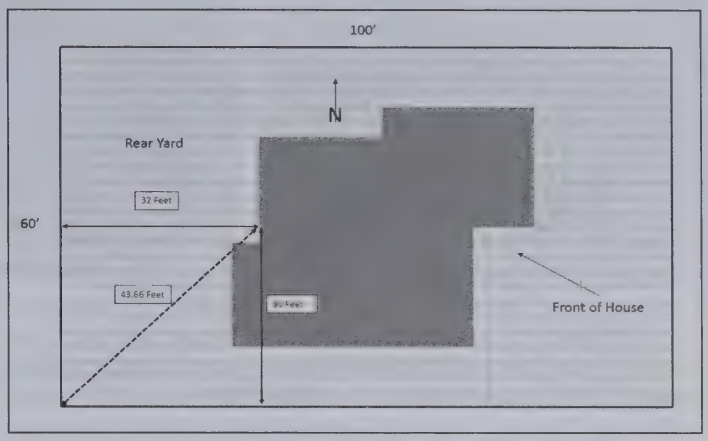

Figure 1—A sketch of the house and lot, showing what I had to work with.

• Next I looked at the house structure itself to assess the suitability as a support structure as there are no large trees on the property. For my antenna solution I considered three antenna types: including beams, verticals and wire antennas. So, the house structure was evaluated based on these three antennas. In the case of verticals, some options exist for either ground mounting or elevated mounting. Looking at my sketch, I could see that ground mounting of a vertical would be somewhat problematic especially if I wanted to install 32 radials as the postage stamp sized back yard was only 60 feet wide by about 32 feet deep and that would place the vertical square in the middle of the back yard. Enter XYL objection number 2. For an elevated mounting at least 4 radials per band would be required and if one of the commercial four band verticals were used that would mean at least 16 elevated wires. So that too was somewhat problematic as that would require radials all over my roof and some of those would, by design, have to extend to the front of the house. I will just abbreviate it: NM. So the vertical was eliminated as a possibility from the mix

• In my new (late 1970s) home there is a chimney at the rear of the house that stands a full 17 feet high. That certainly has some possibilities as a support for a beam antenna, and for such an installation, one could use a commercially available "chimney mounting" kits. Essentially this kit consists of metal bands that go around the chimney and ultimately affix a corner mast mounting device (MMD). This MMD in turn is the support structure for the mast, rotator and beam antenna. This approach would work very well for a "Hex Beam" either a commercial kit or a homebrew version as these beams are light in weight and have a small wind surface area. Given that approach it would appear that the maximum reasonable height for the antenna would perhaps be about 30 feet. While certainly much better than some sort of indoor attic antenna, a beam 30 foot high is a compromise. A quick cost calculation revealed that this option would be in excess of $1200, just for starters, and includes the hex beam, chimney mount, support mast, rotator, coax cable, control cable, guy wires and miscellaneous mounting hardware and parts. Having just spent a fortune on moving, my radio budget just could not support that level of expenditure. So perhaps when things get better financially that would be an option. What ever happened to the $29 Gotham beam antennas?

• So now I was down to wire antennas. As usual in most Southern California tract homes, virtually all properties have grape stake fencing around the rear yards. In my home the base of the rear fence is elevated by about 6 feet as my house is actually lower than the house directly behind me. So I see that as a plus in that one end of a wire tied to that rear fence would be about 10 feet above ground. I found a location on the rear of my home such that if I constructed an inverted vee with an apex of 26 feet, the one leg to the rear fence would be about 47 feet long. (This is nothing more than high school geometry requiring two calcula-

Figure 2—Antenna mast location.

Figure 3—The completed antenna.

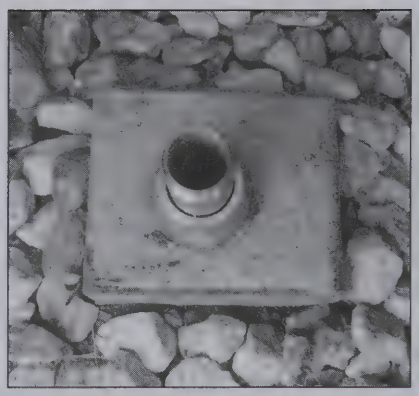

Figure 4—Antenna base.

Figure 5—The bracket mounted to the eave.

tions.) Wow! Now we are cooking. So now on to the demo version of EZNEC and simulation of such an antenna. It turns out that an Extended Double Zepp (EDZ) for 20 meters has each leg element at about 44 feet long, which will work with my 47 foot available length. [Note: I made the legs a bit longer since it will be used in an inverted Vee configuration.] The EDZ exhibits a 3 dB gain so now we are super clocking the wire antenna. The other leg is not a problem as one of the 44 foot legs to the rear fence is on the side with the 10 foot setback. So there is more room for the other side. If I feed the antenna with 450 ohm open wire line, then other band possibilities exist.

Now I had the base line information on a wire antenna and a location on my house (see Figure 2). So, the problem becomes how to support the EDZ that will be built in an inverted VEE configuration. Attaching it to the top of the chimney only gives a 17 foot height. I needed something taller. Certainly the chimney mount would provide a support structure for a mast extending above the 17 foot level and the cost for that alone is about $150. On the plus side is that once installed, if I elect the beam option down the road, that critical piece will already be in place. On the negative side, I would have to climb on the roof and installing the bands on the chimney may be more than a one person job. No, the XYL will not climb on the ladder!

So that is when I decided on a mast approach and purchased some heavy duty telescoping fiberglass poles. The mast approach meant I could "push up" each antenna section from a level of about 5 feet off of the ground and thus avoid the roof climbing experience. These poles available from sources such as DX Engineering, come in 8 foot lengths. I wanted to be certain that when telescoped there would be a certain rigidity to the poles as that also would minimize the guying requirements. The largest size is 2.5 inches which I opted not to purchase, based on cost, but instead started with the 2 inch size and purchased 4 poles that individually telescope into each other and are slotted at one end for purposes of clamping the sections together. Four poles with the minimum required one foot overlap would give you an effective height of 28 feet. I opted for a somewhat larger overlap on the top two sections based on the rigidity criteria and ended up with a 26 foot high antenna. The erected antenna can be seen in Figure 3.

I don't wish to over simplify the final costs nor the construction necessary to deploy the antenna and so each element will now be covered. I already had a 9:1 high power balun acquired when I had the extended Lazy H at my former QTH (NM). However that alone cost is about $150 and it weighs several pounds as it is good for 10 kW. I did purchase all of the parts needed to build the antenna from DX Engineering as they were having a "free shipping" deal on orders over $99. Just think for a moment about the cost to ship oversize fiberglass poles across the US and the answer is purchase the package deal. So with the antenna wire, center insulator, end insulators, guy rope, stainless steel clamps and the four poles the cost was about $175. We are now at about $325. Add in 67 feet of 450 ohm line which I bought from HRO and that is another $35. I already had a run of RG-8U that I brought with me from the former QTH so that was not an additional purchase. The only additional costs were for the base construction such as a bag of concrete, some wood for the forms, the bottom support pipe that would be placed in the concrete and other miscellaneous materials including a six pack of beer rounded the cost out to almost exactly $400. Not cheap but about 1/3 of the cost of the beam that may not have full capability at 30 feet.

Time to play structural engineer and think for a second or two about turning moments, vector forces, wind loads and the effects of temperature on materials. OK a moment has passed and we are done—now time for some "practical engineering". First, the mast has to sit on some sort of base and this base should also provide an anchor point so that the bottom of the fiberglass pole does not move outward. The base should also have the ability to align the mast assembly so that it is vertical from the outset. Secondly, the base should elevate the mast from direct contact with the ground yet support the weight of the mast, the 450 ohm line, the center insulator and the wire antenna. The vector forces are all in the vertical plane of the mast and ultimately impinge on the base structure. Figure 4 shows the base I built. More in a moment on how I scientifically determined where the base needed to be located.

Now a word about pipe diameters and plumbing pipe versus diameter used on fiberglass poles. Suffice it to say that 2" in one world is not the same in the other. I bought 1-3/4 inch plumbing pipe thinking it would fit inside of the fiberglass pole—it didn't and I had to purchase a reducer and nipple so it would now be 1.5 inches. This was smaller than the inside ID of the fiberglass pole and I wrapped vinyl tape around the reduced section until there was a snug fit. This later turned out to be just ideal as it also protects the inside of the fiberglass pipe from wearing and abrading. See Figure 5.

Stop! Don't rush out and start placing concrete until you know exactly where to dig the hole for the base! [Note I didn't say pour

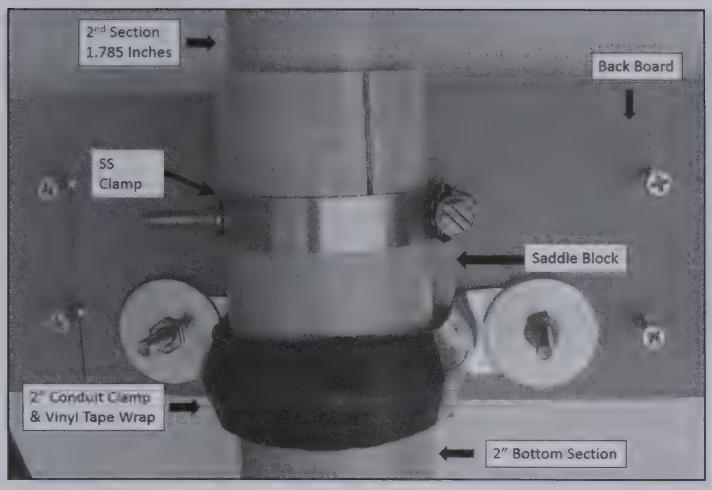

Figure 6—Bracket construction details.

concrete. After spending 4 years in the US Navy Civil Engineer Corps one learns the more precise term of place versus pour.] Now how to find "X marks the spot" and for that I first had to construct a house mounting bracket which will affix the top portion of the first mast section to the house structure.

Since I didn't want to permanently scar the wood framing of the home nor interfere with the gutter system I used a two piece house bracket. The first piece is made from 1 x 4 inch pine about two feet long and is essentially U-shaped so that the two legs are snug up against the joists. Using an elegant method of large C clamps with a wood block spacer, I was able to clamp the assembly to the joists. The bracket is now very solid and I might add easily removable. The front portion of the U bracket becomes the base plate for mounting the house bracket assembly. The house bracket was painted the color of the stucco so it looks like it fits. Figure 5 shows the U assembly and elegant clamps and Figures 6 shows the bracket details.

Now how to locate the position of the hole. Temporarily install just the House Bracket without the bottom pole installed onto the base U assembly—yep more C clamps. Now fashion a plumb bob from a chunk of string, a pencil and a weight. I wrapped one end of the string around the pencil and dropped it through the Conduit clamp. Using the pencil to straddle the hole, I eyeballed where the center of the hole was and then observed where the string hit the ground. The weight keeps the line taught and by rolling up the excess line on the pencil achieve a condition where the line is centered in the hole, the line is taught and the weight just touches the ground. Mark the spot on the ground. I had a 10 inch spike and shoved that in the ground for location X. You don't want the foundation too large as you might have to remove it someday and yet big enough to do the job. My final base section was 5 inches by 6 inches on the surface and below grade was about 12 inches deep and somewhat wider. After digging the hole I made a wooden form out of 1 x 4 pine that gave me the 5 x 6" finished form that sits above grade by about 4 inches. The pipe support with the nipple sits about 5 inches above the top surface of the base section..

A word about the construction of the house bracket shown in Figures 5 and 6. The unit consists of a back plate that is made from pine 1 x 4 by 8 inches long and a 2" electrical conduit clamp that at the point of contact with the fiberglass pole is wrapped in vinyl tape. This is so the metal does not abrade the fiberglass pole and creates a snug fit in combination with the wood saddle block that sits in between the fiberglass pole and the backing plate. This saddle block is made from another piece of pine that has a V shape cut in the wood so that pole is cradled between the block and the clamp. I used a large rasp to convert the V shape to more of a saddle shape. When the clamp is cinched up the fiberglass pole is at 90 degrees with the back plate, does not move and when in place will cause the bottom section to be in a vertical plane.

Once the hole is dug and the form built this is where some small rocks and several short 8 inch pieces of rebar play a vital role in this installation. Now is the time to assemble the first bottom section in the house bracket and to temporarily install the house bracket plus 1st fiberglass pole section on the wood structure. As I was raising the assembly to the house, I slipped the pipe section into the bottom of fiberglass pole and then it went into the hole. So now we have the pipe in the hole, the small wood concrete form around the pipe and the house bracket C clamped to the backing plate. You remember in the list of parts was a six pack of beer—time to have one before proceeding. This will help in the next series of critical actions.

For the next steps, you will need the small rocks, the short pieces of rebar, a short 5 foot ladder and a large level. Begin with the level and "rough in" that the fiberglass pole is vertical by moving the level around the pole while moving the pole in the hole to assure it is vertical. Once there, next carefully place some of the small rocks in the hole around the base of the pipe. This is so when the concrete is placed the pipe won't move. Perform another series of measurements that the pole is still vertical. Next insert the rebar at diagonal angles in the hole to provide additional strength to the base. Once again make sure nothing has moved. As a final check observe that the bottom of the reducer section will be above the top of concrete form. The final step is to anchor the form on the outside so that it doesn't shift when the concrete is placed. Time for another cold 807 (or like here in Southern California, an 805 which is a popular brand that I think has something to do with the area code.)

I mixed the concrete in a plastic tub until the consistency was such that it was not runny nor like heavy paste. This is critical so that the concrete cures properly. Leaving everything in place including the bottom pole section, you are ready to place concrete. Once that is done, take one more series of vertical measurements to insure that everything is vertical and then smooth off the top with a trowel. So yes, you can write your call in the concrete if you so desire—or maybe a thumb print. I did neither.

The next day, carefully remove the forms but wait two more days before doing any more work on the antenna mast. You want the concrete to cure properly. In the intervening period, you can build the rest of the antenna. By the way, I screwed the forms together so that removing the concrete form requires only a screwdriver. After three days final installation can begin.

Building the antenna involves several additional elements including cutting the wire to length, installing the antenna and feed line on the center insulator and installing the end insulators. This seems straight forward but more effort went into this part than finding "X marks the spot" for the concrete base. The DX Engineering center insulator, as I found out after I had it in hand and after once again reading the catalog info, actually comes in

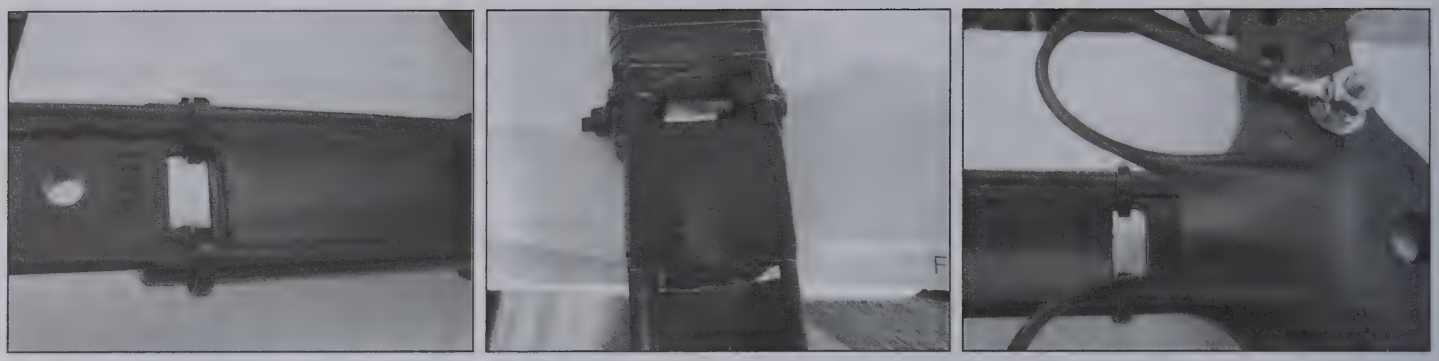

Figure 7—Center insulator details.

two variants, a low power version and a high power version. It is not quite clear what is the demarcation between these two and I did not get a succinct answer from DXE. But I can tell you that I have the low power version and ran 1500 watts into that hummer and nothing melted. So at QRP levels, the low power version will do just fine.

The center insulator is also designed so that the balun can be affixed right to the insulator. That is something I reasoned would not work for my installation given the weight of the 10 kW balun sitting on top of a semi-flimsy mast at 26 feet in the air. My choice was to ground mount the balun which I will cover in detail a bit later on. The DX Engineering center insulator physical design was intended for use with 300 ohm twin lead. I talked to DXE about this as to the choice of 300 ohm feedline. It seems it was a higher cost factor for 450 ohm line versus 300 ohm line and what they stocked for feed line. That to me sounds like the tail wagging the dog. But once again enter "practical engineering" and 450 ohm line can be used with the center insulator by using some cable ties and vinyl tape. Figure 7 shows how this is done. I sent this info to DX Engineering as I thought they might be interested in how it could be used with 450 ohm line as I am sure others have inquired. If one goes from 50 ohm coax to 300 ohm line, that requires a 6:1 Balun which is not common. But, a 9:1 Balun which would transform 50 ohms to 450 ohms is quite common.

As I said, this part was more difficult than the X marks the spot exercise. Couple that with the supplied hardware for the center insulator missing some critical parts and it makes for a frustrating experience. So, I strongly recommend counting the nuts and bolts in the hardware bag as a first step and just purchase the missing pieces, in my case 10-24 stainless steel nuts, from Home Depot or a local hardware store.

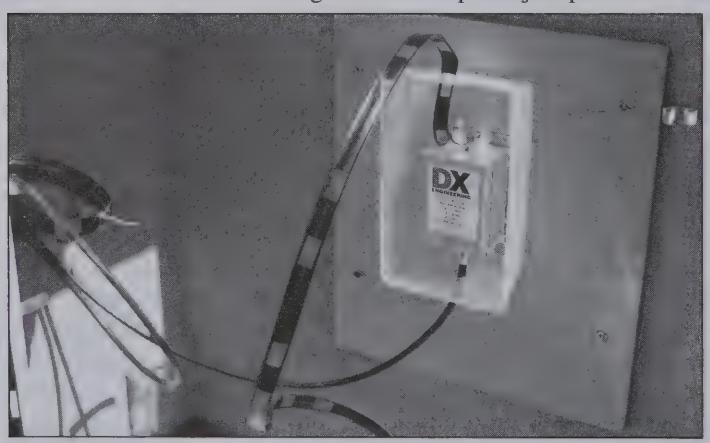

Figure 8—Balun and enclosure

That said, I must commend DX Engineering for the design of their end antenna insulators. These insulators are designed so that you can cut the length of the antenna legs longer than needed and the internal features enables making the antenna length shorter without cutting wires. How many times have you heard some ham say they had to add wire to their antenna because they cut the length too short. The critical factor is, when initially cutting the wires, make the overall length longer than needed and insure the length of each wire to the center insulator is the same. Why? Because in pruning the antenna you only have to deal with shortening the SAME amount on each end insulator and each antenna leg will mirror each other.

Now, back to the Balun mounting. I noted in my initial site survey that the prior owner had something attached to one of the back walls which had been removed as there were four "lead" type anchor points in the stucco. I mapped those four points and using a piece of 1/2 inch thick outdoor pressure treated plywood which was painted the same color as the stucco proceeded to drill four holes so the plywood could be attached to the four anchor points. This solved several problems as the mounting plate was several feet off of the ground. Using a plastic enclosure provided a barrier so there was no possibility of touching the exposed contacts. This installation is shown in Figure 8. For good measure, I took about five turns of coax and formed a loop of about 8 inches in diameter which I cable tied to hold the loop structure. Presto! I had a choke balun in line with the 9:1 balun.

So OK how does it work? Well I would say in comparison to an indoor attic antenna—far better. In comparison to my former extended lazy H, far worse. That said, I have worked some far east DX such as 9V1 and BY9 plus several contacts with South Africa on 20M. But, that was running QRO—1500 watts helps. During the Hawaii QSO party in August of 2013, I made six QRP SSB contacts on 20M all with good reports. So indeed the band of design seems to work OK. However Europe seems to be a black hole as the orientation of the antenna does not favor the northeast. It does quite well on 75 and 40 Meters, most likely because it is a cloud burner exhibiting NVIS characteristics. On 30M, it does OK but nothing spectacular. So at best it is a compromise, but certainly orders of magnitude better than an indoor antenna. This project is all about working with what you have at hand. Never Move!

—72/73, Pete, N6QW

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Ionospherica

Kazimierz "Kai" Siwiak—KE4PT ke4pt@amsat.org

How Dipoles Radiate—The Hiker's Bent Dipole

Pedestrian HF mobile is a delightful way to combine amateur radio with trail hiking. In the previous Ionospherica we the big picture of the Earth-Sun system that governs the behavior of the ionosphere. We also saw how reflections from earth interact with an antenna to form vertical standing waves that vary the signal strength at different antenna heights. But what if the antenna is at ground level? What if half of the antenna lies on the ground? Ed Breneiser's, WA3WSJ, pedestrian mobile trek inspires this episode [1]—the hiker's antenna and its radiation properties. The concepts carry over to other antenna that use a counterpoise.

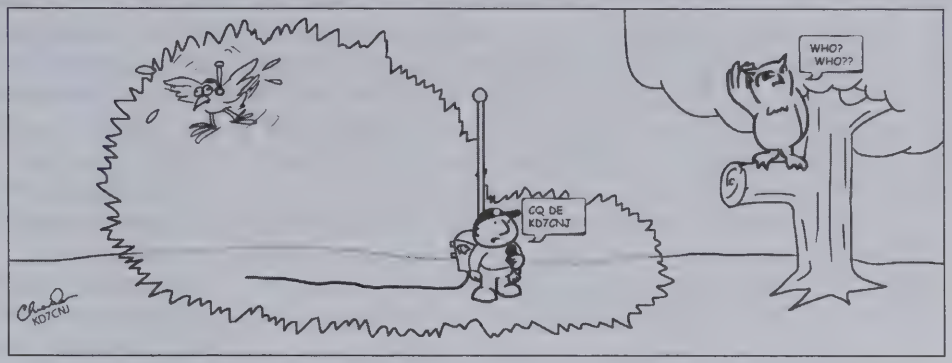

Figure 1—The hiker's HF portable antenna has two elements: a vertical whip, and a trailing wire. These elements form a bent dipole that has directional properties. ***Copyright © 2014 Chris Dean, KD7CNJ, used with permission***

The hiker's antenna seen in Figure 1 comprises two antenna elements. One is a vertical whip above the backpack radio, and the second is a wire that drops to the ground and trails behind the hiking radio operator. Since both the vertical whip portion and the trailing wire portion contribute to the radiation, the antenna pattern of this "bent dipole" is far from omni-directional.

The stylized envelope surrounding the hiker suggests a directional antenna pattern. A hapless bird behind the hiker "feels the heat", while the "who-ing" owl in front remains less than well illuminated. This is the story of how the hiker's bent dipole radiates, its directional characteristics, and how it couples to the ionosphere.

We'll confine our discussions to wire antennas with elements that are each generally less than a quarter wave long, but otherwise this story is relatively independent of frequency. Also, we don't require that the wire elements self-resonate. That's a detail we handle by antenna matching circuits, or with an automatic antenna tuner.

It Takes Two to Tango

Dipoles by definition have two ends. Radiating electric fields connect between those two end points to radiate. Said another way, there are no monopole antennas in isolation. However, an image of the antenna in a "mirror" such as a perfect electric conductor (PEC) can take the place of the second element. However we do it, there must be a counterpoise below the whip element protruding from the backpack radio—a second dipole element.

Figure 2 portrays the electric fields of (A) a dipole, (B) a monopole with a perfect image in a PEC of infinite extent, and (C) a bent dipole entirely above an earth ground. The dipole is in isolation, that is, it is not near ground. There is a certain symmetry in the elements, but they need not be

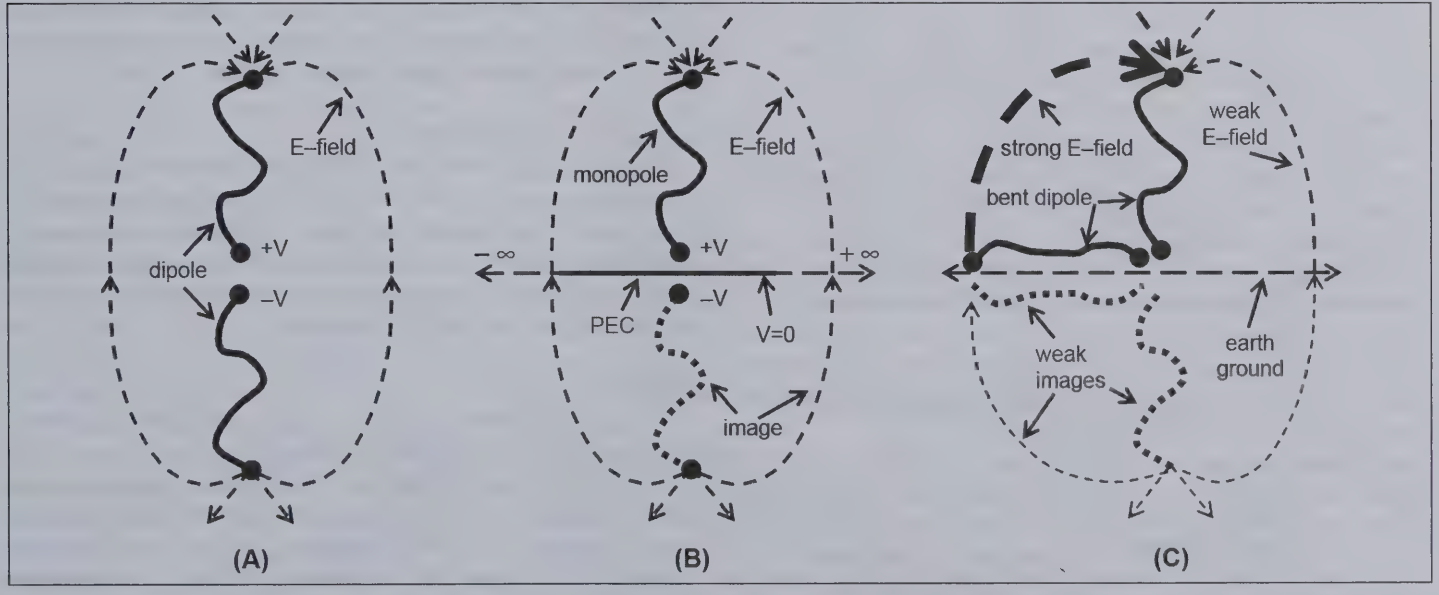

Figure 2—An electric antenna, like a dipole (A), needs two ends or tips that attach the E-field lines between them. In an arrangement (B) over a PEC one half of the dipole appears as an image in the PEC, including image fields. A bent dipole (C) above an earth ground has a weak image in the ground, and weak image fields, and has directional properties.

straight, and they may include loading elements such as inductors. Apply a balanced voltage, +V and –V to the feed terminals of the dipole. The electric fields that appear around the dipole seem to emanate primarily from a pair of "point sources" at the two tips of the dipole elements. These fields are depicted by dashed lines in Figure 2. Note that the fields, like those between the plates of a capacitor, originate at one end and terminate at the other end of the dipole. That holds true whether the dipole is in isolation (A), or is a an element against a counterpoise (B), or is a bent dipole (C) near the ground.

Indeed, this two-point source picture conforms with the exact mathematical expression for the total fields of a half-wave long dipole fed at a single frequency [2]. It takes a pair of terminals to feed the dipole. It takes two end points to radiate the electric field.

What if Earth Were a Copper Sheet

We can rely on a mirror image to take the place of the lower dipole element as in the configuration in Figure 2 (B). The monopole, of course, is not a complete antenna. It needs an image in the mirror—a counterpoise. We feed that antenna with an unbalanced voltage +V against a PEC (or our imagined copper Earth). The PEC provides the second terminal for the return current path of the feeding voltage +V. It also provides the mirror image of the monopole tip, with its opposite charge, so that the electric fields can terminate properly and therefore radiate.

How much of a counterpoise do we need? We've portrayed an infinite half space of PEC in Figure 2 (B). However, we can get away with far less. That leads us to the Hiker's Bent Dipole

The Hiker's Bent Dipole

The vertical whip element and a wire trailing on earth ground is about as minimalist as one can get to realize a dipole for the trail-walking backpacking radio-toting ham. We portray that dipole in Figure 2 (C). Now the earth ground is not perfect, the ground images are weak, but we do have two elements with two distinct end points, and we have two feeding terminals.

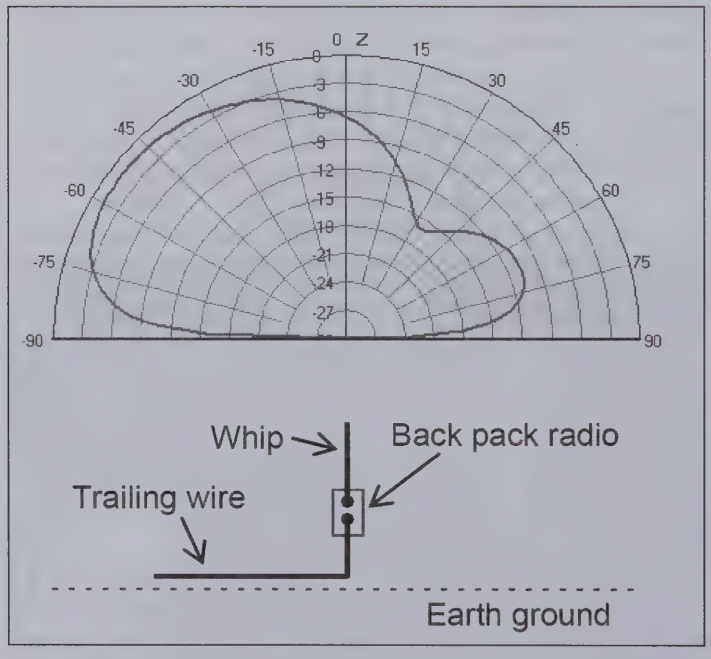

Figure 3—Calculated elevation pattern of the Hike's Bent Dipole. The rear to front ratio is nearly 10 dB.

We've lost the symmetry evident in (A) and (B), but we've gained a configuration that is very suitable for pedestrian mobile—a dipole with a vertical whip element and a trailing wire element. Both elements are equally important to the radiation process. As depicted in (C), the bent dipole will tend to have a comparatively strong electric field joining the two wire ends, and weaker fields interconnecting the weak images in the real earth ground.

Consequently, the the bent dipole will favor radiation in the direction of the trailing wire.

Antenna Pattern of the Hiker's Dipole

We can simulate the performance of the Hiker's Bent Dipole using Numerical Electromagnetic Code (NEC), such as EZNEC [3], or 4NEC2 [4] using the geometry shown in Figure 3. The pattern in the plane of the bent dipole has a back to front ratio of nearly 10 dB. The back to side ratio is about 5 dB. Thus the hiker experiences about two S units stronger signals from behind compared to the front, and about one S unit lower to the sides compared to the rearward direction.

The pattern seen in Figure 3 has a broad elevation pattern peak between about 15 and 60 degrees above the horizon, and has significant signal coverage down to 5 degrees above the horizon. That's suitable for coupling into the ionosphere for long distance communications as well as for shorter hops.

While this "hiker's beam" antenna requires some additional hiking to make it rotate, at least now you know the favored pattern directions.

Estimating Radiation Patterns

Figure 2 provides us with some insights into how we can qualitatively estimate radiation patterns and radiation polarization. Rather than worrying about how the currents flow in the wires, observe how the E-fields must form to connect the farthest two ends of a dipole. From Figure 2 (C) we can estimate that the polarization in the rear and front directions is essentially vertical. However, the fields emanating to the sides of the hiker are polarized half-way between vertical and horizontal.

Summary and Conclusions

The bent dipole model lets us estimate the performance of the hiker's antenna very conveniently. Peak signals with a broad elevation pattern are behind the hiker, and antenna polarization varies from vertical to the rear and front, to a significant tilt towards the sides. We can use the same technique to estimate the radiation properties of mobile antennas.

References

1. E. R. Breneiser, WA3WSJ, "Colorado QRP Pedestrian Mobile or Bust." *QRP Quarterly*, Winter 2014.

2. K. Siwiak and Y. Bahreini, *Radiowave Propagation and Antennas for Personal Communications*, Third Edition, Artech House, Norwood MA: 2007, Chapter 11.

3. EZNEC from R. Lewallen, W7EL, available at www.eznec.com

4. 4NEC2 from A. Voors, available at www.qsl.net/4nec2/

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'Failed State' Electronics

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If you don't ask yourself, "why do things fail?" You are missing the most exciting part of your electronic hobby. When you have a piece of equipment that fails, do you just throw it away? Analysis of the failed item can be the most interesting part of your electronic experience. It can lead to new designs or modifications to improve your equipment.

Most of our current electronic equipment is designed to be replaced at the subassembly or Printed Wiring Board assembly level, but that doesn't prevent you from trying to find the root cause of a failure at the piece part level. Sometimes your investigation will lead to a simpler repair action that will save the subassembly or unit.

Electronic components can be studied on Wikipedia at http://en.wikipedia.org/wiki/Electronic_component. It has a large data base on how these parts work.

The Science of Deduction

It is keen to apply the precepts of Sherlock Holmes in these matters:

"It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts". (*A Scandal in Bohemia*).

"When you have eliminated the impossible, whatever remains, however improbable, must be the truth". (*The Sign of Four*, Ch. 6)

"The world is full of obvious things which nobody by any chance ever observes."

Statement of the Cases

I have left out all the fluffy and verbose descriptions that Dr. Watson would have added if he were recording these stories, so you will have imagine your own settings, but some of these stories did begin "On a Dark and Stormy Night."

"Many of these singular happenings have never before until now been fully dealt with in any public print".

The Episode of the 'Black Widow' Transistor

One of the most devious failures ever encountered involved the "Black Widow" transistor in a push pull switching power supply. Female Black Widows have been known to eat their mates. The guy spiders still have not figured this out.

This failure occurred on a TO39 power transistor (2N3553) that had a big copper slug inside the case that was crimped in place. The case had three dimples on the side of the case that grabbed the internal copper header.

In this singular case one transistor in the circuit burned up and shorted, it looked like a secondary avalanche breakdown, collector to emitter short. There was significant melting of the part. The transistor was replaced and after a few temperature cycles the newly installed transistor failed again in the same spot. Ahaa!—the spider got another one.

The root cause of the failure was traced to the 'good' transistor in the push pull pair. It was opening up and latching the other one 'on'. The crimp on the header can was the only electrical connection to the collector and when it opened up the other transistor was turned 'on' with full DC current that just melted it. So remember in any push pull circuit failure the 'good' part might really be the 'bad' part, however improbable it may seem.

The Midnight Flight of Denny Dendrite

It was a dark and stormy night, really, when the intrepid Denny Dendrite electronic sleuth made his way carrying a dendrite to a secret laboratory in Washington, D.C. for analysis. Arriving at 3 a.m., after a transcontinental flight in the winter, a dozen government investigators stood ready at their SEM and Auger equipments.

The defect had just been confirmed on an integrated circuit that had used leaded (Pb) glass sealing material. The surface of the sealing glass had provided a platform for pure lead dendrites to grow from one IC lead to another under high impedance electrification.

These were easily visible using a microscope. Indeed, a movie of the growth progress was made for the IPC tilted, "Denny Dendrite". Trace Labs has a Dendrite You Tube video:

http://www.youtube.com/watch?v=uyO-XE-Q9ZQ

These types of failures are frequently induced by taking a unit from a dry, cold environment into a warm humid environment causing the unit to go through the dew point. When that happens, water condenses out of the air and can cause dendrites. There is usually enough carbon dioxide (CO_2) in the air or acidic residue on a circuit board to start a dendrite growing. So do not apply power to a unit that has gone through or is going through the dew point until it is completely dry. Remove any memory battery back up battery or it will cause new dendrites.

The use of "Freeze Mist" for trouble shooting is highly discouraged because this causes frost to build up on the components and they all get wet as they come back through the dew point. Obviously it can cause dendrites that will mask the clue being investigated. Elementary isn't it? If you must lower the temperature of a part, use an ice cube in a plastic bag.

The Intermittent Green Radio

This radio performed perfectly for many years, but it was infrequently used. After field testing in hot weather, the unit would fail after a few hours. The radio has many internal protection circuits so it just shut down and no internal damage was found. The radio would work fine the next day.

Troubleshooting began at the power supply circuit and using a heat gun, the unit could be made to fail quickly when it was hot. Switching to a soldering iron to gently heat the components the failure was isolated to a tantalum capacitor. The capacitor was physically reversed in its circuit and after replacement there was no more intermittent high temperature failure. Tantalum capacitors typically can operate for many hours in the reversed polarity direction, but will eventually short out.

The printed circuit board did not have any polarity markings on it and it escaped visual inspections. This expensive radio was repaired for the cost of a two dollar part. Many articles about capacitors can be found on the Kemet.com Website.

http://www.kemet.com/kemet/web/homepage/kechome.nsf/weben/technical%20papers

Another similar failure occurred in a similar radio that was caused by an over heating TO-220 Transistor. The transistor was mounted with small insulated plastic bushing to keep the mounting screw form shorting to the chassis. During assembly the bushing/washer became smashed under the transistor body and this prevented the TO-220 transistor from fully seating on its heat sink. The transistor was not able to dissipate the heat on its case and that caused the radio power supply to shut down. Reseating the transistor flush onto the heat sink fixed the unit.

The 3.5% Solution

It was a warm sunny day on the Island of St. Lucia when a rogue wave crashed over the rocks and drenched the HF operating site. The main radio was drenched and was inoperative. You could almost hear the dendrites growing. The operator, who was without his regular gear, rushed the radio to a clean water source to rinse it out to flush the salt water out of the rig.

Ocean salt water is about 3.5% saline. After drying the radio, it again began to work. The normal lab procedure would be to wash it with distilled water, then an alcohol rinse followed by a vacuum bake. If a vacuum bake is not possible the radio could be dried in an oven with MIL-D-3464 desiccant or a bag of rice.

The Curse of the Tin Whiskers

If you have a good microscope, with a magnification of at least 15x, you can find these tin whiskers in your old parts bin. Just look for an old USECO stand off. These old insulating turret stand offs where tin plated and have over the years grown tin whiskers. You can see them growing off the top terminal. They are extremely small (Perhaps 1/20 the diameter of a human hair but up to 1/4 inch long) they are straight and shiny. If you catch them in light reflection, the whiskers are easy to see. There are several Tin Whisker videos on YouTube:

http://www.youtube.com/watch?v=goyWEYGKPrQ

You can find them on Wikipedia: http://en.wikipedia.org/wiki/Tin_Whiskers

The whiskers can cause shorts and multipactor discharges. Using parts that have a small percentage of lead mixed with tin eliminates this problem. It occurs on silver and zinc plated parts also.

The Episode: "Scintillation of a Tantalum Capacitor"

Have you ever seen the 'scintillation' of a tantalum capacitor?

You can be 'Sherlokian' and find these defects and see what makes these things fail.

Wikipedia is a great place to learn about the construction, application and failure modes of components. Check out: http://en.wikipedia.org/wiki/Tantalum_capacitor for a briefing on tantalum capacitors.

You can see the capacitor scintillation on a transistor curve tracer. Just slowly run the voltage up on the capacitor to three times over its rating, with about 1000 ohms in series and it will scintillate right before your eyes. The manganese dioxide (MnO_2) melts down and plugs the tantalum (Ta) dielectric performing its well known "self healing" effect. If you don't have enough series resistance in your circuit this capacitor can explode.

Sometimes the capacitor manufacturer puts the wrong tantalum slug in the can or marks the can with the wrong rated voltage. You can strip the manganese dioxide (MnO_2) off of a failed slug and tell by the color of the slug what the real tantalum oxide thickness is and what its real voltage rating should be.

One of the best ways to insure that your replacement tantalum capacitor doesn't fail again, without redesigning the circuit to make it more reliable, is to 'surge test' the capacitor.

There are dozens of papers on this technique at the NASA Electronic Parts and Packaging (NEPP) Program Website: http://nepp.nasa.gov

The Electrostatic Discharge League

There isn't enough room in this monograph to cover the many ESD failure analysis techniques. With a curve tracer you can an easily see MOS FET input/gate damage.

Go to the Electro Static Discharge Association web site for more training information.

http://www.esda.org/education.html

ESD Rule:

Keep your wrist strap on and your soldering iron grounded. Remember "The contact and separation of unlike materials causes static".

The Case of the Open Case

Cold temperature failures of the venerable JANTX2N2222A and 2N2907 led to the discovery of this major manufacturing defect. One qualified manufacturer was making the TO-18 headers by filling the bottom with a glass sealing powder. You probably have some in your junk box. The collector lead connection to the header and thus to the transistor die was a pressure point contact that was held fast by the contracting sealing glass during formation of the seal.

The reliable construction design of other manufacturers had a silver pellet on the tip of the collector wire and it made a metallurgical 'nail head' weld to the header during the glass seal operation. This problem was also found on ground leads on TO-5 cases also.

When TO-5 part replacement was not an option, nickel wire was welded to the cases and soldered to ground. See cross section pictures and GIDEP Alert RW-A-79-01 for more details.

The Cracked Solder Joint Mystery

Solder joints are our friends but they can be defective if they are 'cold solder' joints or if they are mechanically pulled apart. Any part that is fixed/mounted on one side of a PCB and has leads that go through and are soldered on the other side are candidates for solder fracture.

Long periods of temperature cycling will also cause solder fractures. Don't leave your gear out in your unheated shack over the winter. These fractures cause open circuits and can be seen easily with a microscope. Many solder joint failures can be induced by subjecting the item to very cold temperatures for a long time and then applying circuit power while they are still cold.

Multiple Cases, Same Solution

Many cases have the same defect at the root cause. This can provide many benefits to the electronic sleuth making detection and solution easier.

- Many TS-440 radios have been found with similar symptoms. They frequently loose VCO lock on 28 MHz and just display dots. This is caused by a mate-

rials defect in the VCO cans. The manufacturer used foam potting material to keep the components stable for mobile operation. This foam fooled a few NASA Space engineers too. The foam reverts into conductive sticky goop after 10 or 20 years in humid environments. The conductive foam shorts out all the high impedance circuits. The repair is to simply remove the goop and clean the VCO cans out. It is called 'reversion" but it is really 'degradation'.

• Many foreign engineers use polarized aluminum capacitors as audio coupling capacitors. Audio is AC and the negative part of the audio voltage can de-plate the capacitor dielectric causing audio distortion. The symptom is usually reported as "Transmitter works good but receiver has distorted audio". I have purchased several radios with this same symptom for junk prices and by changing one capacitor, I now have a good radio. These radios usually come out of packet systems where the squelch is left off and the radio runs around the clock. This design technique works for a radio that is always squelched and used infrequently, but used in full time service they may only last 10 years.

Elementary Equipment Needed for These Analyses

Only the most basic equipment is needed for these analyses, but it should include— multi meter, curve tracer, microscope or a small magnifying glass and a small hacksaw.

Danger: *Some components are made of hazardous materials!*

- Don't grind up any beryllium oxide (BeO) which is white looking ceramic. This material is used on many power semiconductors.
- Some capacitors have carcinogenic or acid electrolyte.
- If it smells bad throw it out.
- Don't mess with mercury relays or 866 mercury vapor tubes.
- Don't dissect radioactive sources.

The Epilogue and Additional Clues:

1. Wikipedia <http://en.wikipedia.org/wiki/Electronic_component>

2. *Handbook of Electronic Components and Circuits*, John D. Lenk, Prentice-Hall.

3. *Electronic Components Handbook*, Henny and Walsh, McGraw-Hill.

3. The Jim Williams Papers, *EDN* 1991.

4. *Trouble Shooting Analog Circuits*, Robert A. Pease, National Semiconductor Corp, 1989.

5. *IEEE Reliability Physics Proceedings*, Read all you can find.

6. *International Symposium for Testing and Failure Analysis (ISTFA) Proceedings*, Read all you can find, 1970 to 2000.

7. MIL-STD 1580A, "Destructive Physical Analysis."

8. *The Adventures of Sherlock Holmes*, Sir A. Conan Doyle

"I can't give you a more detailed account of these cases without referring to my notes.

"I do not know anything essential that has been left unexplained".

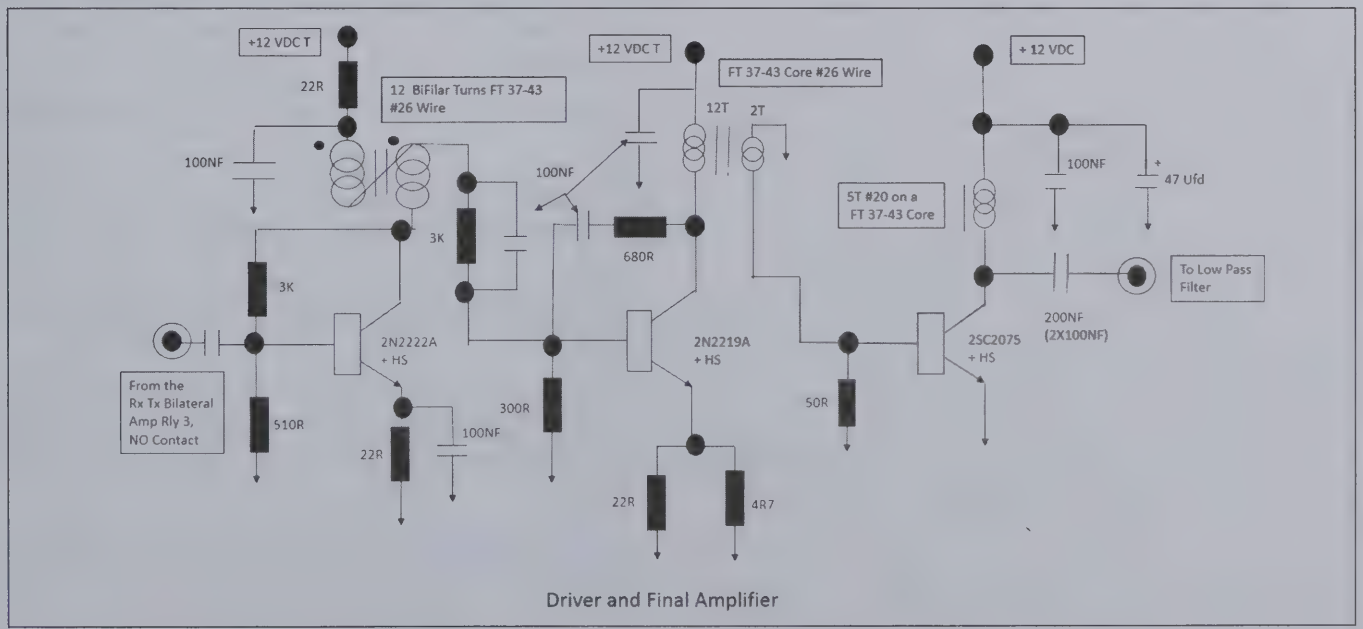
The game is afoot.

—de WØRW

Erratum: 30 Meter CW Transceiver (Fall 2013 issue)

In the Fall 2013 issue of *QRP Quarterly*, the 30 meter CW transceiver article by Pete Juliano, N6QW contained two errors in Figure 11, the schematic for the driver and final amplifier stages. The resistor in the base of the 2N2219 labeled 3k ohms should be labeled 300 ohms. Also, in the feedback loop from collector to base of the same 2N2219 stage, the feedback loop showed a 100 nF capacitor and 680 ohm resistor in parallel. This is in error. The feedback loop should show the 100 nF capacitor and 680 ohm resistor in series.

A corrected Figure 11 is shown here.



Driver and Final Amplifier

FDIM
Four Days in May
May 15-18, 2013
The Premier North American QRP event

FDIM 2014 is just a few months away and "right now" would be a great time to start making plans. Here's a quick guide for first-timers and regulars alike—

What is FDIM ?

FDIM or "Four Days in May" is the annual convention of QRP ARCI. It is held in Dayton, Ohio and runs concurrently with the famous Dayton Hamvention®.

When is FDIM ?

In 2014 FDIM starts on Thursday 15th May and ends on Sunday 18th May

Where is FDIM ?

We take over the Holiday Inn at Fairborn, it's a pleasant area near Wright State University and around 20 minutes from the Hamvention venue. All FDIM activities are at the Holiday Inn—just about every guest in the hotel is a QRPer! There is a good selection of restaurants within walking distance.

What happens at FDIM ?

• Wednesday 14th May:

Check in at the hotel and collect your FDIM badge and goody bag in the evening. This is a great time to meet up with old friends

• Thursday 15th May:

A full day of seminars from 8am to 4pm. Fours draws are held during the seminars and a TEN-TEC transceiver will be presented to four lucky winners.

Buildathon and Pizza Party.

An evening presentation (subject to confirmation).

Vendor Night—avoid the Hamvention crowds. Buy kits, antennas, books and components right in the hotel.

• Friday 16th May:

Attend the Hamvention—use the buses that we run from the hotel direct to the Hamvention entrance.

QRP Club Night —promote your local club and enjoy the hospitality of other clubs. It's a lot of fun, with games, and music later in the evening.

Enter one of the Homebrew Construction competitions. Entries are displayed for all to see and everyone attending joins in with the judging.

• Saturday 17th May:

Attend the Hamvention again. The buses will be running to Hara Arena.

The FDIM Grand Banquet is held Saturday evening. Food, drink and great company! Door prizes are drawn (usually several THOUSANDS of dollars!). Awards are made and speeches are short. The QRP Hall Of Fame inductions are announced.

• Sunday 18th May

Attend the Hamvention if you want, then make your way home.

Who will speak at the seminars ?

• This year we have:

George Dobbs, G3RJV
The Classic World of the Regenerative Receiver
Gary Breed, K9AY
Why Does My Rig Have a Receive Antenna Jack?
Dave Cripe, NMØS
POW QRP
Craig Behrens, NM4T
The Great Arduino, JT65 and Rebels Caper
Harold Smith, KE6TI
Many Ways to Homebrew
Chris Testa, KD2BMH
Whitebox Handheld SDR

What else ?

FDIM is "not just about the radio"! It's a social event. You will make new friends and meet people who are well known in the QRP world. First timers can be identified from their FDIM badge, everyone is encouraged to say "Hi" to those who have travelled on their own. Participate as much as you want. Spectate or join in, it's up to you.

What can you do to help ?

Everything that happens at FDIM is done by volunteers. Checking people in, handing out badges, selling bus tickets, taking publicity photos, manning tables, selling raffle tickets, supporting vendors, elmering at Buildathon . . .

Helping out is very rewarding—give something back to FDIM !

Where can I find out more ?

Go to the FDIM webpage: **www.qrparci.org/fdim**

Register for the Seminar ($40) and Banquet ($35) online on the FDIM page. Payment is by PayPal or credit/debit card.

If you register online you will be entered in the seminar draws to win a TEN-TEC transceiver. Registering by mail or at the hotel will not qualify for entry in the drawing.

To book a room call the hotel direct—details are elsewhere in QRP Quarterly and on the FDIM webpage.

Check **www.qrparci.org/fdim** for updates !

FDIM

Four Days in May

15-18 May, 2014

Wednesday evening Registration and get together

Wednesday evening is registration and getting acquainted.

Thursday a full day of Seminars

Seminars are most of the day Thursday, with "meet the speakers" and an open room for some casual show and tell. **Vendors** will be setup on **Thursday evening only** this year.

Friday daytime, take a break or attend Hamvention

Friday daytime is open to attend the Hamvention® and visit the QRP-ARCI Toy Store. The hotel will supply some gathering space.

Friday evening activities include "show and tell" and the Homebrew Contest judging. We are **adding an invitation** for QRP clubs to bring their banner and other goodies to set up tables on Friday. It should be great fun to share your clubs activities.

Friday Evening Judged Competition Home Brew Displays Club Tables

Saturday is again open for Hamvention. For the evening, and we have our great **annual banquet**, awards presentations and door prizes.

Sunday is the Hamvention®, and check-out.

Guest/Spouse Program

FDIM Registration and Hotel Reservation

Home Brew Contest	Door Prizes
Special Activites	Discounted Hotel Rooms
Banquet	Complimentary Breakfast
Seminars	Hamvention just across town
Meet the Speakers	Nearby Restaurants
Vendor Displays	New Product Announcements
Discounted QRP Products	Spouse Program

Much More! Watch the web site www.qrparci.org

Thursday Afternoon TBD

Thursday Evening Vendor Night

Thursday Evening Casual Show and Tell

Saturday Morning Off to Hamvention or see the sights

Saturday Evening Awards Banquet Door Prizes

This is preliminary information. Some changes will most definitely occur.
Please check the web site, www.qrparci.org, for the latest details and registration information.

Out and About with QRP

Craig Behrens—NM4T craigb44@msn.com

Evolution: From Radio Go Bag to Bug-Out Bag

As I write this (March 3rd) it's just above freezing outside with a 15 MPH+ wind that bites with the sleet it carries. The freeze line is precariously close to Huntsville, Alabama. Nashville, just north of us, struggles with icing issues as their day sets in. It's been a tough winter! Oh Spring time, where art thou?

Hopefully, now that you have received this Spring *QQ*, pleasant weather has set-in where you live. And I hope that your outdoor adventures are already in full swing.

So, this time, let's focus on how we can improve and (therefore) better exploit our QRP portable activities. There are endless ways to engage in such adventures—we'll only be able to take a look at a few, but we'll pick some real gems and include some valuable tips (lessons learned) for you to add to your hard earned collection.

First, let's talk about "missed opportunities." If you're like me, you've had too many times where you could have participated in portable radio adventures, but life got in the way. You're been so preoccupied with (so-called) "high-priority must do now" items that the opportunity came and left. You respond with a (somewhat) pathetic "Oh, rats… That was last Saturday!

Ok, I'm guilty too, so no lecture here, just the reminder that this is the only life we get….

On the other hand, too many of us project manage our outings to aerospace standards only to find that our operational execution is abysmal. And most of us already have some kind of equipment "Go Bag" set-up for short, casual, daytime operations. Or, we simply throw a bunch of stuff in our car, hoping that we didn't forget anything, prior to heading out to play radio.

So now, let's explore what can be done to extend our portable operational capabilities while gaining more utility from our investment. We can use some of my Go Bag configurations as examples that can be examined for further improvement.

The low end of the Go Bag spectrum is simple to assemble. Examples (Figures 1 and 2) include what you might use for casual operation from your favorite park in Parks on the Air (POTA), or for Summits on the Air (SOTA) radio operation. This approach focuses on keeping weight and mass to a minimum. Extreme sport backpacking and SOTA operators literally count in ounces vs. pounds. This type of Go Bag will (usually) include only what you need to operate on a single or a small number of radio frequencies and modes for a very limited amount of time. And, it is great when everything you brought works, but could it could become a disaster if anything fails. Even so, this will be all that is needed for SOTA or casual operations where you simply want to get outdoors and have some fun.

My classic ICOM 703+ with ICOM backpack and rechargeable battery is a good example of a Go Bag that stores just enough equipment to get on the air for a few hours. It barely has enough room for the items you would need to carry. This design does, however, have the ability to use the display a short distance from the main transceiver unit to facilitate pedestrian portable operation and it allows a small vertical antenna to be attached.

The Oriole fanny pack is lighter than the ICOM backpack and it has almost the same amount of storage space. Equip-ment is placed inside the various compartments and then the tensioning straps are tightened to protect its contents while traveling. One important feature that these two bags share is that they both have built-in rain covers that can be deployed when needed to better protect your gear.

So far nothing's changed, but things will start to get interesting when we adopt a few Rapid Deployment Amateur Radio (RaDAR) and some survivalist "Bug-Out Bag" principles. Our Go Bag configurations morphs into something quite different and our operational activities expand with new purpose as we pursue these.

I'm not suggesting that we all become die-hard "Preppers," but wouldn't it be great to have a portable operations bag that actually includes everything you will need. And, better yet-wouldn't it be wonderful to have it ready and waiting to be grabbed to address emergency situations, as well as fun portable radio outings?

I am suggesting that you take a significant step to add some additional communication capabilities, computing functionality and navigational abilities to your Go Bag. Or should I say "System in a Sack (SiaS)," as Eddie Leighton, ZS6BNE, creator of the RaDAR group refers to such bags.

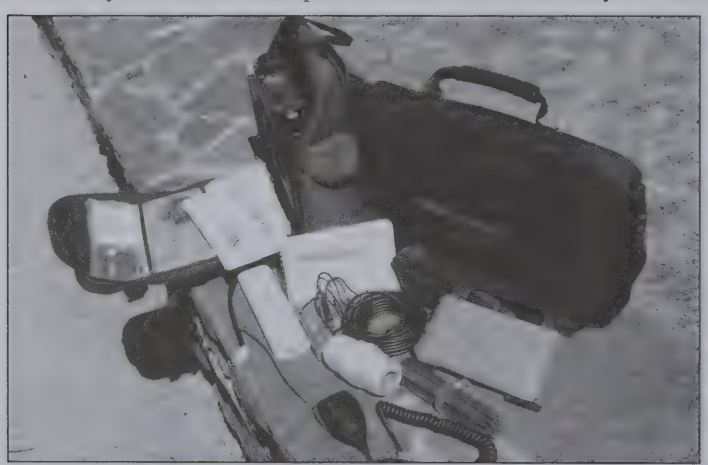


Figure 1—ICOM-703+ with ICOM backpack setup.

Figure 2—K1 or Rebel with Kelty Oriole fanny pack setup.

Figure 3—LowePro 170AW (All Weather) camera bag.

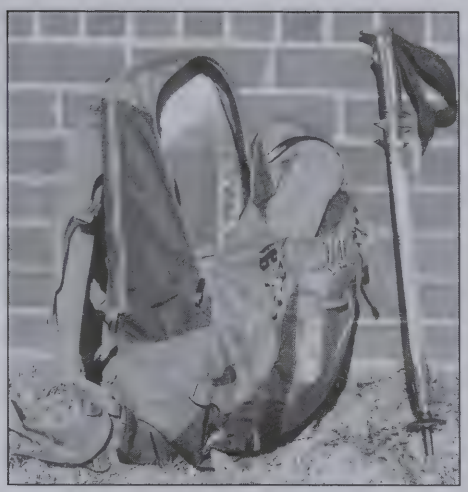


Figure 4—Camelback Fourteener backpack (with LowePro as insert).

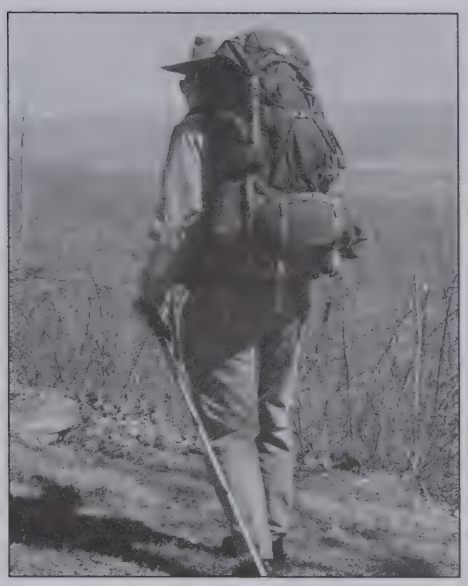


Figure 5—NM4T's Gregory Baltoro-65 "Bug-Out" backpack.

As low-end examples, I have two Go Bag configurations we can use as typical RaDAR SiaS Go Bags for short outings. The first is a LowePro 170AW (all weather) camera bag that can be used standalone or as an insert that goes inside a more comprehensive Go Bag set-up (Figure 3). This bag contains everything needed to get my KX3 (with built-in tuner and internal batteries) on the air. It has earphones, compact headphones/MIC, hand MIC, Palm CW key and an EndFedz 10/20/40 QRP antenna, as well as cables, adaptors, etc. This bag can be carried via the shoulder strap or belt mounted.

Also notice that my iPhone and handy talkie are integral parts of this configuration. I also show documentation, but that could be stored in the iPhone to make room in the bag for something else of value.

My second RaDAR SiaS example for day trips employs a Camelback Fourteener Backpack (Figure 4). It's amazing how much "stuff" you can get into this small bag! If you look closely, you can see that it contains a hydration system, complete with a drinking tube and an internal water bladder. This is strategically located between you back and the load you are carrying for added comfort. This small backpack allows me to carry rain gear, a change of clothes, a first aide kit, snacks/food, etc. Further, I can carry my LowePro 17AW radio equipment bag separately, or I can insert it into the bottom of the Fourteener bag for travel when I require fewer travel support items.

This example moves us closer to a Prepper's Bug-Out bag kind of capability that assures that his Bug-Out pack can provide everything required getting him from his home to a "safe" destination within 24 to 48 hours.

Before we move to my camping (longer term) backpack SiaS, let's discuss RaDAR for a moment to further differentiate it from casual radio operations.

First, as stated in the Google+ RaDAR Community's blog [Ref. 1], RaDAR is multi disciplined—it promotes the use of all methods of communications available to radio amateurs (including the use of satellite communications and cell phones) and it promotes the use of basic survival techniques that help operators gain experience with self sufficiency.

Second, RaDAR contact exchanges differ from other forms of radio operations by creating field operation opportunities that practice the communication of accurate positional information that is useful for navigation as well as for informing others of your precise position.

For example, my Maidenhead grid location is EM64. But having this information will only get a rescue helicopter to a general area. If someone is trying join me, or I am trying to navigate to a particular location-this resolution of positional information has limited value—especially if a life is at stake.

So RaDAR operators also gain experience for accessing and communicating grid locators to the 10-character accuracy (or even finer latitude/longitude detail) such situations.

And third, the thing that makes RaDAR operation most different to other amateur radio activities is the ability that RaDAR operators gain to move quickly. A typical RaDAR field operation activity, for example, would involve setting-up your station, doing 5 QSO's, and then moving a kilometer (or more) and then repeat the process at the new locations.

If you examine a RaDAR operator's SiaS more closely—you'll notice other significant differences. For example, you'll notice that a cellphone (or similar device) often become a key, multifunctional component of their SiaS. So, even if you don't have cell coverage where you're going-you can exploit your cell phone's computing power, its information storage capability as well as the convergent technologies it offers. This helps you extend your operational capabilities to log contacts, to access GPS, to serve as an additional communication mode when needed, to record audio (QSOs, verbal or written notes), etc. It's also a great place to have important info stored and readily available (such as maps, etc.). You'll also notice that RaDAR operators bring their handy-talkie radios, not just for QSOs, but also to serve as another form of communications.

Getting back to Go Bag configurations-I exploit the sophisticated design of my Gregory Baltoro-65 backpack to achieve my most Prepper-like configuration (Figure 5). At this point, we're getting close to my physical load bearing limitations by assembling a Go Bag that includes as much gear as I can personally manage.

Figure 6—High Sierra suitcase with removable backpack.

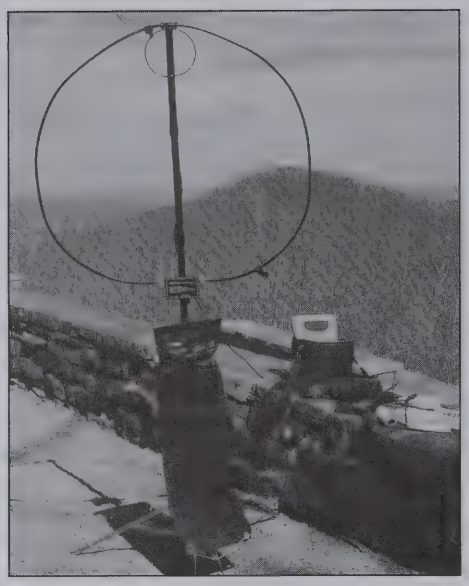


Figure 7—AlexLoop and backpack solar charging setup.

As you would expect-tough trade-offs must be implemented vs. how much radio equipment, camping gear, personal items and food/water, etc. comprise such a configuration.

I have this bag ready for emergencies, and I store it in our tornado shelter when we have bad weather approaching. It includes a 3-person tent, a sleeping bag, a larger hydration system larger first aid kit, lights, stove, cooking gear, food (plus trail snacks) and more. Its contents will evolve as I gain more experience using it.

Before we end this short discussion about Go Bags, I'd like to share a new discovery I made that might serve you well with air travel as it did for me on my Buddies in the Caribbean Suitcase DXpedition to St. Lucia. As I packed my gear for this trip, I discovered that the suitcases I had were either too big or too small. After looking around in several stores, I came upon a great deal for a High Sierra suitcase that had a detachable backpack (Figure 6). Since I'm usually on small commuter planes to and from Huntsville, carry-on luggage is usually a problem—they want to check most carry-on bags into the belly of the plane. This is not a good place to put my (precious) radio gear.

The great thing about this suitcase is that I can detach the backpack to place it in the small overhead compartments and then place the remaining part completely under the seat in front of me-problem solved!

Speaking of obstacles, one of the biggest obstacles to overcome with portable operations—where A/C electricity sources are not available—is that of recharging batteries. Ok, you can use a car's system to do this, but what can you do when no cars are available?

I been experimenting with some solar charging equipment (Figure 7) and I have developed a new appreciation for the challenges that this approach presents. Batteries that discharge via radio operation in a few hours can take more than a day to recharge via portable solar panels. Worse yet, you can't depend on getting acceptable sunlight when needed, especially in weather emergency situations.

If you decide to get a solar charging set-up, be sure that it's one that can be hooked-up and charging your battery while you is on the air. This will provide you with more operating time and it can often reduce the amount of charging you battery may require.

In addition, your cell phone, computing equipment and such all will also require an answer to this dilemma. On my last outing, I discovered that laptop computers deplete their battery charge faster than radios in high-usage situations (such as meeting the processing demands of JT65).

Obviously, there is a lot more to be said, but let's just transition to this quarter's challenge instead:

As you may have surmised, my challenge for you this quarter is twofold: First, invest in making improvements to your Go Bag to extend its intrinsic value, and second, invest in your ability to gain valuable experience with the aforementioned techniques in your next outings.

Now that we have briefly discussed a few Go Bag examples, it would be wise to take a sharper and more holistic look at our portable operation bags. We should assess how well our Go Bags address "The Ten Essential Systems," as defined in the book *Mountaineering: The Freedom of the Hills* (The Mountaineers Books, 2003).

How well are you equipped and trained to address the following items?

1. Navigation Systems (map, compass, GPS etc.)
2. Sun Protection (clothing, hats, sunglasses, skin protection creams)
3. Insulation (extra clothing)
4. Illumination (headlamps, LED flashlights, batteries, solar panels)
5. First-aid supplies
6. Fire (matches, fire starters)
7. Repair kit and tools
8. Nutrition (extra food)
9. Hydration (extra water, purification capability)
10. Emergency shelter and signaling devices (mirrors, radios, SPOT devices)

Of course, A.R.E.S., storm-spotting and other activities would also become more effective, perhaps even empower hams to save lives, by how prepared they are to address these.

Hopefully, this short article has provided you with some new improvement ideas and it has stirred you into action to refine your portable operation capabilities. (I'd love to get hear about your bag configuration and improvements via email and/or in person at FDIM.) I trust that the improvements you make will serve you well, not just for casual radio operations, but also for those unplanned emergencies that could (and do) happen to us along the way.

In closing, I'm reminded of the TV ad that asks, "What do you have in your wallet?" Instead, I'll suggest that we Hams should be asking our peers "What do you have in your Go Bag?"

—72, Craig, NM4T

Reference

1. RaDAR Community: https://plus.google.com/u/0/communities/109283065808971118728?cfem=1

CW Sender: An Aduino Based Project Series

Ben Kuo—KK6FUT (kk6fut@verizon.net) and Pete Juliano—N6QW (radioguy90@hotmail.com)

A chance meeting on 20M led to the discovery that we are both QRP enthusiasts (one with years of ham radio design experience, the other a new ham with little radio design knowledge but with years of software development background) and that not only did we live in the same town, but just a few blocks away, Thus was born a collaboration on using the Arduino microcontroller for a multitude of QRP radio applications. This first article is to provide some basic background on the Arduino and to take that information in a step by step approach so that the reader can develop their own applications. By the end of this first article, you'll be able to send some simple CW on the Arduino's LED. Grab a cup of coffee, a spot of tea or your favorite cold "brew" and let us begin the journey.

What is the Connection Between Arduino and Ham Radio?

As new technology advances and finds its way into our beloved hobby, we have grown to expect certain capabilities as simply standard. We want our radios to be on frequency and not drift. We want T/R switching to be seamless and without fits and starts. We want to be able to accurately measure things such as frequency and power output. We also like to do it on the cheap without the need for exotic and expensive or worse yet simply unobtainable parts. As QRP enthusiasts we also think about small size, portability and low power consumption. Oh, did we mention having a digital display for everything? We are not asking too much—are we?

Turns out we aren't asking too much. In fact, we have a way to do the things we mentioned already and lots more as well. Enter the Arduino, which has revolutionized the hobby market from a home beer dispensing system (a real project) to robots and lest we forget Ham Radio. Figure 1 shows this marvelous gem, the Arduino.

We can think of the Arduino as a "Black Box" (Figure 2) with input and output ports that, through the marvels of software, can be configured to perform a myriad of tasks. It is not necessary to know what is in that black box but simply to know what and how to tell it what to do. Here are some ham radio examples that can be and are being done with the Arduino, where the heavy lifting is done with the software and very little external hardware is required:

- CW generator for code practice, contest keyer, a CW bug, keyboard sending and even visually seeing what is being sent
- Frequency generation. Using inexpensive DDS modules, the Arduino can be configured to provide a multitude of frequency outputs. [One such Arduino/DDS combo has been retrofitted by one of the authors into old boat anchor equipment. Imagine what this combination can do for older radios that perform well except they drift—a lot.]
- Remote VFO's
- T/R sequencing, so there is no "hot" switching.
- A general purpose signal generator.
- Solar Power Charge Controller
- Controller for a 10M beacon.
- RF measuring device/SWR Bridge
- Station Control/Linear Amplifier Control (definitely not QRP)
- 10 Minute ID reminder + CW sender
- Two Tone Tester
- CW "Ditter" (auto sending of dots for transmitter testing)
- Remote Antenna Tuner

TEN-TEC has even taken the Arduino a step further with their Rebel. The Rebel, a hot new offering from Tennessee, is a CW QRP radio employing an Arduino-like PCB and open source software. This revolutionary concept enables the end user to "get in the loop" and experiment with their radio. How exciting, as our hobby takes a new turn in the road.

We hope to cover many of the projects mentioned above, not only in this article but several additional articles in this series.

Platform Recommendation

A tour through the auction sites or retailers like Amazon or distributors like Mouser, Digi-Key, and Radio Shack will show that there many flavors, sizes and variants of the Arduino. Some of these are bargain priced and there is a temptation to have price drive the selection—yes hams always want things on the cheap. But everything comes with a price and until one develops all of the skills needed to make the variants play the same, it is best to use a single model for this project series. A single model also avoids the problem of spe-

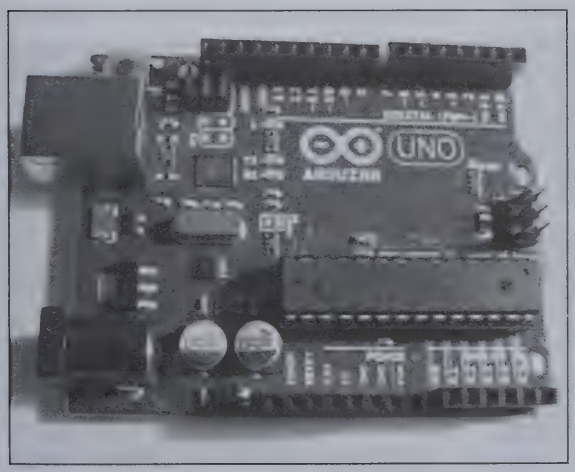


Figure 1—Arduino Uno R3.

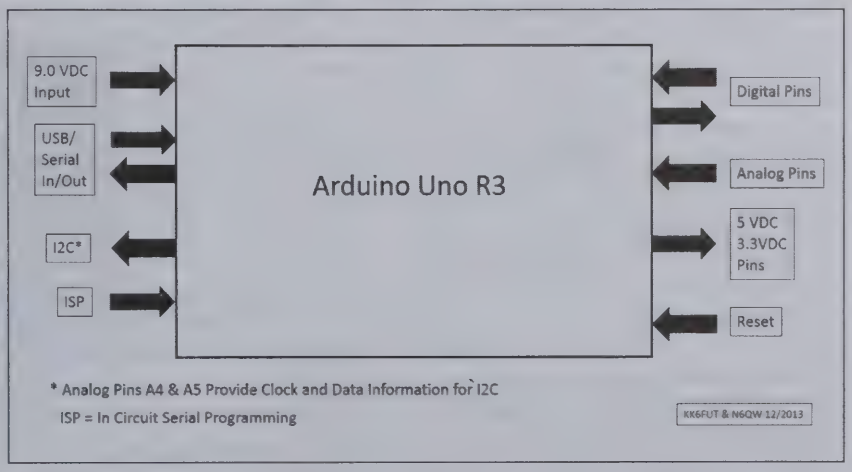


Figure 2—Arduino as a "Black Box."

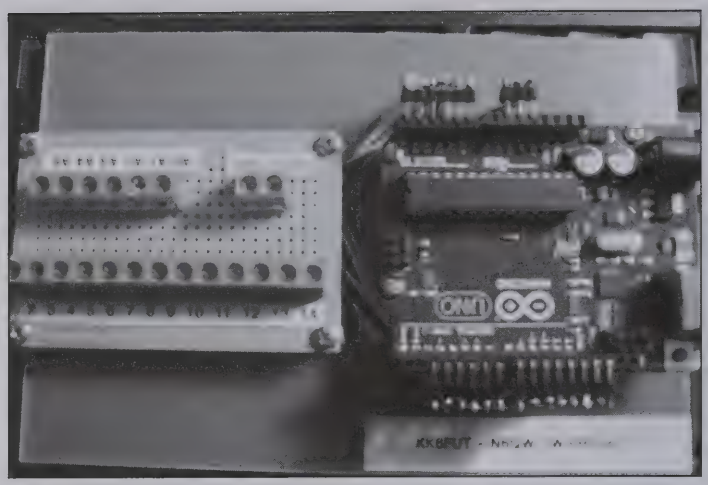


Figure 3—Experimental platform.

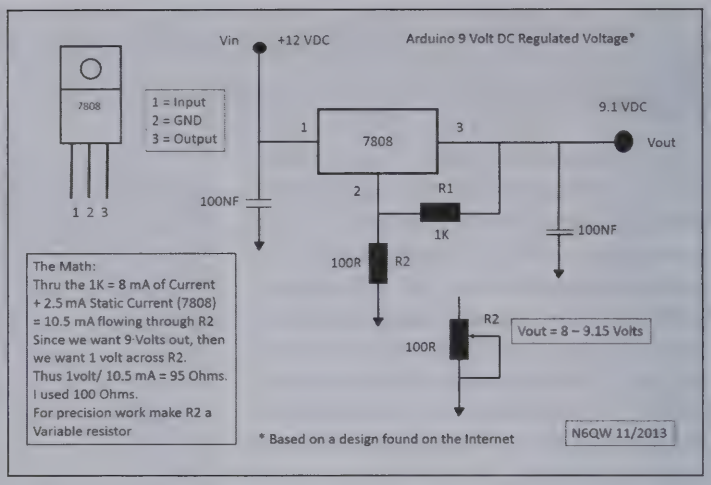


Figure 4—12 VDC to 9 VDC converter circuit.

cial cables or interfaces to access pin connections, a feature of some of the smaller footprint Arduinos. Also, the authors have experimented with several of the variants and found that not all Arduinos (especially the clones) are 100% compatible with the various software libraries and functions. Finally, we have found that not all peripherals are compatible with these variants.

So for this series of articles, we have settled on using the Arduino Uno R3. This model luckily is stocked by the major distributors for quick delivery and does not require waiting 3 to 4 weeks for that slow boat from China to arrive. All of the software presented in this series and the peripheral hardware recommended has been developed and tested on this model of Arduino and it works. Save yourself some grief! Use the model we have specified and later, as your skill set develops, feel free to experiment with other models.

Arduino Hardware Construction

The Arduino, as shipped, will arrive at your shack looking like Figure 1. While the Uno R3 is a relatively rugged little board, repeated insertion into the terminal header on the board can cause a whole range of problems, starting first with smoking* the board, breaking off of the header, insertion into the wrong pin header etc. In addition, as the Arduino board moves around in the lab, there is a high probability that the underside of the board will contact metal. In fact, while this is not a true Arduino software statement—it should be!

*If the underside of the board contacts any metal objects at the computer station = smoked parts... *[This is good advice for any prototyping. For good results, you need to make sure that parts are stable and protected from accidental contact with a conductive surface. —Ed.]*

So, we recommend setting up your Arduino on the experimental platform shown in Figure 3. Details of the platform are explained on the webpage at www.jessystems.com/arduino_build.html. This page also contains an Excel spreadsheet showing the listing of parts and corresponding sources. The small amount of time required to make the platform will be well worth the effort. Primary purposes of the platform are to (1) protect the Arduino board from shorts and (2) provide a reliable method of connecting the board to various ancillary parts in our series of projects. Ultimately, we will need input connections for a CW paddle, Keyboard, Power Connector (and power conditioning), and CW speed control. Output connections will be needed for an LCD screen, speaker and TTY terminal. The breakout board to the left of the Arduino board provides the terminal blocks for these interconnections. Numbers close to the terminal blocks correspond to specific Arduino pins, which are often referred to in the associated software. This gives you a leg up in routing the correct input/output pins to their proper home. At some later time when you are ready to install the Arduino in an enclosure, the 4 x 6 PC board will fit

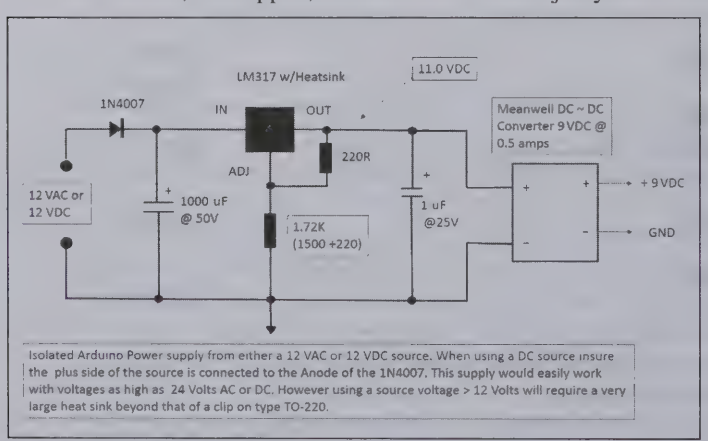

LM317 w/Heatsink
11.0 VDC
1N4007
IN
OUT
ADJ
220R
Meanwell DC ~ DC
Converter 9 VDC @
0.5 amps
12 VAC or
12 VDC
1000 uF
@ 50V
1.72K
(1500 +220)
1 uF
@25V
+ 9 VDC
GND
Isolated Arduino Power supply from either a 12 VAC or 12 VDC source. When using a DC source insure the plus side of the source is connected to the Anode of the 1N4007. This supply would easily work with voltages as high as 24 Volts AC or DC. However using a source voltage > 12 Volts will require a very large heat sink beyond that of a clip on type TO-220.

Figure 5—9 VDC isolated supply.

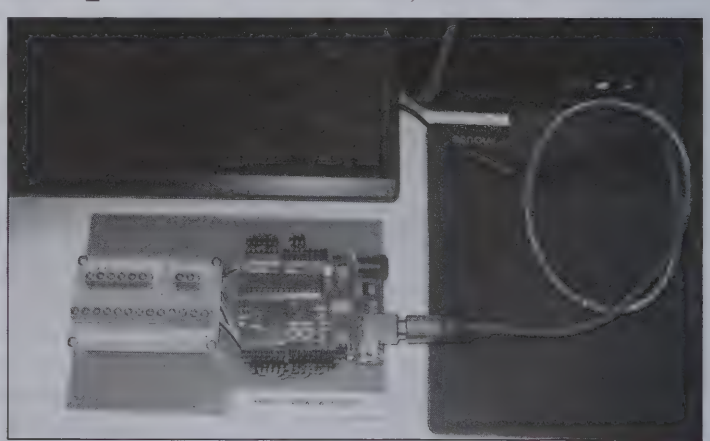


Figure 6—Aduino connected to a PC.

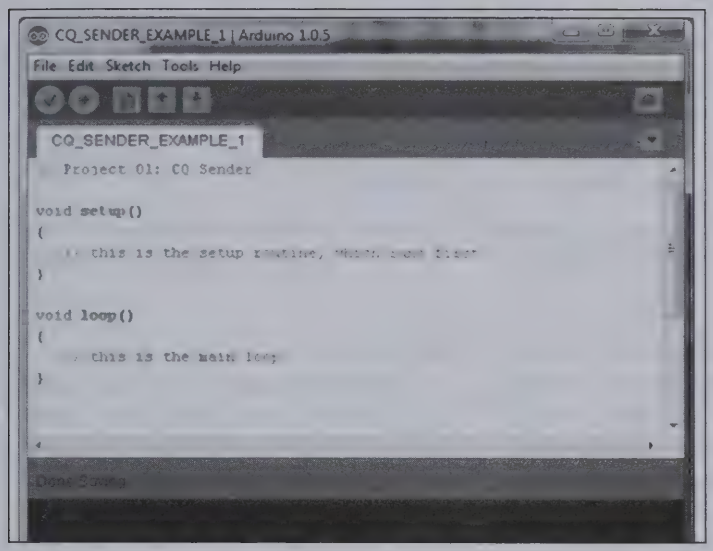


Figure 7—The first sketch.

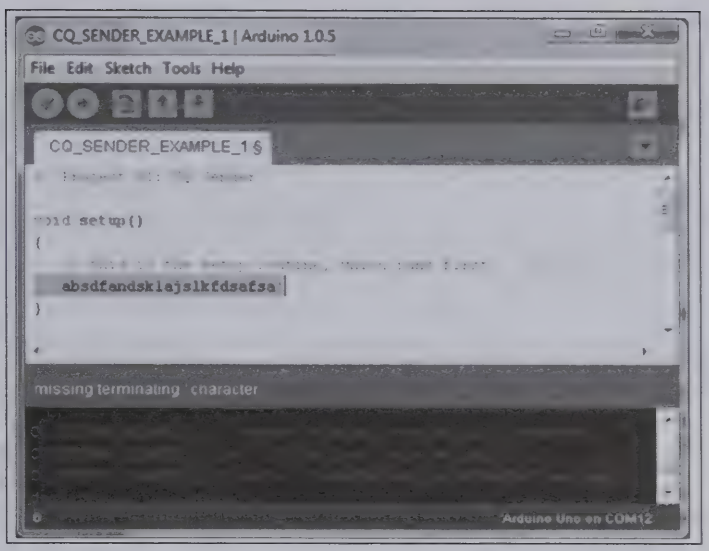


Figure 8—Error message.

in a standard 5 x 7 enclosure.

You will also need some means of powering the Arduino when it is not connected to a computer's USB port. While the input voltage to the Uno R3 can be wide ranging, there seems to be a favorite of 9 VDC at up to 1 amp, depending what else is being powered by the source. This power can be furnished by a 9 VDC @ 1 ampere "wall wart," but quality of these devices can be suspect. You may prefer to use the 12 VDC to 9 VDC converter of Figure 4 in conjunction with a nominal 12 VDC power supply on your workbench. Alternatively, there is the isolated power supply shown in Figure 5 that will work with AC or DC voltages up to 24 Volts. The isolated supply was developed by one of the authors so that a Uno R3 driving a DDS VFO could replace the analog VFO in a tube type boat anchor. The input power source was the 12.6 VAC filament string.

The Software Connection

In this article, we want the reader to have a solid grounding in how to construct the software so that the basic foundation is in place and developing code for your projects has a basis, a reason and it works. We hope to avoid the pitfalls of saying "do this," "push that" and "pull here." We want the "tribal knowledge" factor to be minimized so that developing your code is a seamless proposition. Our target audience is the newbie who wants to get their feet wet and not get drowned in the process.

Warm up the computer as it is time to "code the Arduino input." Later on, you can warm up the soldering iron!

Understanding the Arduino Software Environment

As we move forward in using the Arduino for our radio projects, one key area to understand is the software environment used to develop, compile, upload, and debug software on the Arduino.

The key parts of the software are the software program loaded onto the Arduino (called in the world of Arduino the "sketch"), the software editing/development environment (launched from your PC as "Arduino"), the drivers for your Arduino (there are separate drivers for each of the Arduino variants; we use the Arduino Uno R3), and supporting libraries that are used to support additional, advanced functions.

The first step to using Arduino is to connect your device to your PC. This is done through a simple, USB serial cable, which you connect from your PC's standard USB port directly to your Arduino's USB port. (See Figure 6 for an example.) The Arduino draws its power supply directly from USB, so when your Arduino is attached to your PC, you do NOT need to use the separate, external power supply. When your Arduino is connected to your PC, a green LED on the board (PWR) will light up. (Caveats: You might need to connect your USB cable directly into your PC motherboard or front connectors; some Arduino devices do not behave well with USB hubs. If you see a rapid blinking LED, you might be encountering this issue.)

Loading the Arduino environment onto your PC is the next step. This involves going to the Arduino website, http://arduino.cc/, and downloading and installing the full software environment—and drivers—for the Arduino. Your PC should automatically load the drivers for the Arduino Uno R3; if not, there are detailed instructions on the Arduino reference guide/website on how to manually load the drivers.

The next step is simply something to be aware of: the concept of a library. A library is essentially a pre-developed set of software code, which you can easily call from an Arduino sketch, to accomplish some function. There are a certain number of system libraries, which you use to do everything from read a value from a pin, to wait for a certain amount of time (delay), or to print characters out to the Arduino's serial port. (In the case of Arduino, the serial port is actually a USB port, but shows up to the operating system as an old RS-232 port might appear. We use "serial port" as shorthand here, because that's how the Windows operating system refers to the USB port attached to Arduino.) When you downloaded the Arduino environment, you also downloaded the most basic system libraries for your Arduino. You won't need any other libraries for a while yet. Later, you can also download additional libraries for other functions—for example, controlling a servo motor, displaying text on a certain

```
const int LED = 13;  // LED on Pin 13, built in LED on the Uno

void setup()
{
   // this is the setup routine, which runs first
   pinMode(LED, OUTPUT);  // sets the digital pin as output
}
```

Figure 9—Setup.

```
void loop()
{
   // this is the main loop
  digitalWrite(LED, HIGH); // turn on the LED
  delay(1000); // wait 1 second
  digitalWrite(LED, LOW); // turn off the LED
  delay(1000); // wait 1 second
}
```

Figure 10—Loop.

kind of LCD, or even using the Arduino as a frequency counter.

The Process of WritingCode

Once you have the Arduino environment loaded, you can open up your first program—or as it's called in Arduino, the "sketch." You will write the sketch as a series of English statements with a fixed format. The allowed set of statements and their meaning is shown on http://arduino.cc/en/Reference/HomePage. Figure 7 is an example sketch of the actual software code you develop and load onto the Arduino. Once you have written the statements, the code is then compiled. Compiling is the process of translating the description of the software we've written, and turning that into the machine code—the stream of bytes—which is actually loaded onto the Arduino and which is executed on the device. If you have made an error in any of the code statements, the environment will return an error message telling you what is wrong with the statement. See Figure 8 for an example. The Arduino environment will not then upload your code until you have fixed the error and recompiled.

One key skill you will be learning here is the process of interpreting the error messages and fixing the errors. These errors might be because of an erroneously placed character; a call to a "function" which does not exist; problems with the formatting of your software (called a "syntax error"), and sometimes (but hopefully not) issues with the hardware configuration compared with your software code. To minimize error messages (again) we are using the Arduino Uno for all of our examples, so that there is a consistent set of software, hardware, and libraries in all cases.

Each error message will provide a description of what was wrong with your software, and which line had the error. Your job is to go through those errors, line by line, and try to figure out what happened. In many cases, the software will tell you what was wrong with the line; in other cases, you might have to search through for changes to the code you made which caused the error in another part of the code. In an iterative process of compile, find the error, fix the error, compile again, you eventually end up with a piece of code which compiles and which you can load into your Arduino.

You may find it helpful to compile your code while you are writing portions of it. This can provide a fast way to see if some portion of the code is done correctly. To compile code manually in Arduino, you can go to Sketch > Verify/Compile. The Arduino software environment shows status and messages displayed at the bottom of your editing screen and a green progress bar. If the code compiles okay, you'll see a message stating "Complete." If not, you'll see a list of errors.

Hint: As with any hardware circuit, with software, it's best to make just one change at a time. Change a single statement or line in your code, then compile, rather than trying to make large changes in the code—at least, until you're more experienced at the compiling/debugging process.

Once you have a Sketch which successfully compiles with no errors, you can upload your code by making sure your Arduino Uno R3 is plugged into a USB port, and you have selected the proper type of Arduino and serial port ID. In all of our examples, we've used the Arduino Uno R3, so you will need to go to Tools > Board > Arduino Uno. If you compile with the wrong kind of Arduino selected, the software will be unable to load and you may see some very strange error messages. To select the proper serial port that your Arduino is configured to appear as, using the Tools > Serial Port > menu and selecting the proper COM port. Note that if you happen to have several Arduinos, the computer assigns virtual COM ports for each individual Arduino. Typically the virtual COM port starts with COM3 on up.

To start the upload process, you select File > Upload to upload your Sketch to the Arduino. The Arduino software environment will again compile the software, and upload a Sketch to the Arduino—you will see the LEDs flashing as the software is uploaded, and then an indication that the "Upload is complete."

The Structure of an Arduino Sketch

In covering how to use Arduino with these ham radio projects, and to help you start to understand how to put together your own projects, we'll be talking a lot about the structure of the software for Arduino.

The first part of any Arduino Sketch are some lines of software defining which libraries we may want to use (for example, if we are using the serial port or sound), and what are called global variables and constants—values which do not ever change from when your software is compiled, and can be used as shortcuts within the code. These global variables and constants are used by the compiler but are never actually run as part of the program. In our example, we define a single constant called LED, which we use as shorthand to refer to the pin number for our LED. By using a constant, if we decided to use a different pin number we could just change that number in one place, in the constant declaration, and not have to search and replace the number 13 all across our sketch.

After the libraries, global variables, and constants, come the basic building blocks of an Arduino sketch. Within the Arduino software are functions—basically blocks of software which, like a module on a ham radio, are used for specific things. The first two functions to understand are called setup() and loop().

setup()

Essentially, the first thing that the Arduino's "black box" does is get power.

```
// send a dot
digitalWrite(LED, HIGH); // turn on the LED
delay(100); // wait 100 milliseconds
digitalWrite(LED, LOW); // turn off the LED
delay(100); // wait 100 milliseconds
```

Figure 11—Sending a dot.

```
// send a dash
digitalWrite(LED, HIGH); // turn on the LED
delay(300); // wait 300 milliseconds
digitalWrite(LED, LOW); // turn off the LED
delay(100); // wait 100 milliseconds
```

Figure 12—Sending a dash.

When that happens, the first piece of software which runs is called setup(). See Figure 9 for an example. (Note: The word "void" appearing before setup() just means setup() is not expected to return any information to another function.) setup() is typically used to state which pins on the Arduino we are using, and set those pins high or low to their starting value.

loop()

The main body of the Arduino's software is called the loop(). See Figure 10. The loop is the software code which continually runs (loops) through. This is where most of our software code will be placed. The most important thing to remember about how the Arduino runs is that the software is run continually. Unlike many software programs you may be used to on your PC or elsewhere, the Arduino is designed to run as an embedded system, which means that it is always running once you've loaded the code. There's no beginning or end of the software; it keeps on repeating itself. The simplest example of this would be a software Sketch to blink an LED on and off. This sketch would keep on running forever, until you turned off power to the Arduino or loaded new software.

The First Arduino Project:
LED On and Off

For our first project, we'll be establishing the foundation for the rest of our CW sender projects by walking through a simple LED on and off example. This program turns an LED on and off in regular fashion, which may not seem so fancy but is in fact exactly what we need to build our own software for sending CW via Ham Radio.

In and Out: Not Just A Hamburger Chain

The first step in any Arduino project is determining what signals are going in, and what signals are going out of the "black box." These are called the inputs and outputs. In our first example, we have no data inputs and just one simple output, the LED signal driver. We'll eventually use these outputs to send a tone to a speaker, and to send out a "keyed" signal to your radio.

```
void loop()
{
  // send a dash
  digitalWrite(LED, HIGH); // turn on the LED
  delay(300); // wait 300 milliseconds
  digitalWrite(LED, LOW); // turn off the LED
  delay(100); // wait 100 milliseconds

  // send a dot
  digitalWrite(LED, HIGH); // turn on the LED
  delay(100); // wait 100 milliseconds
  digitalWrite(LED, LOW); // turn off the LED
  delay(100); // wait 100 milliseconds

  // send a dash
  digitalWrite(LED, HIGH); // turn on the LED
  delay(300); // wait 300 milliseconds
  digitalWrite(LED, LOW); // turn off the LED
  delay(100); // wait 100 milliseconds

  // send a dot
  digitalWrite(LED, HIGH); // turn on the LED
  delay(100); // wait 100 milliseconds
  digitalWrite(LED, LOW); // turn off the LED
  delay(100); // wait 100 milliseconds

  delay(1000); // wait one second before it runs
}
```

Figure 13—Sending a "C".

The Arduino Uno has two types of pins; digital input/outputs, and analog outputs. In addition, some of the digital output pins on the Arduino support Pulse Width Modulation (PWM), a technique we won't cover here but can be used for everything from motor control to solar charging. [One of the authors has developed an Arduino solar charging circuit for a remote 10M Beacon transmitter. In addition, the keying and control of the transmitter is all done with the same Uno R3]

For this project, we are using a single pin, digital pin 13. We use this pin because the Arduino Uno already has a built in LED on pin 13. We could use other pins, but that would require connecting a resistor and LED externally (which we will do later in other projects). To use this pin, we do two things: first, we declare a variable (memory) to hold the value of the pin, then we call a function to indicate that our pin is an output.

const int LED = 13; the keyword "const" is, in software speak, a shortcut to tell the compiler that the variable, LED, will NOT change after the software is compiled. Because our pin will not change we declare it a const. Other variables—which we might manipulate later in our software—should not be declared const. We've also indicated that this value is an "integer," which in Arduino is defined as a number between –32,768 to 32,767 on the Arduino Uno (16 bits).

*** VERY IMPORTANT—this is why we picked the Arudino Uno R3, because different variants of the Arduino may declare an "int" as different ranges. This can drastically affect how your

software runs.

pinMode(LED, OUTPUT); next, we tell the software in our setup() function that we will be using this pin as an output. We're using the variable LED as a shortcut to be able to change the LED pin at any time in software without having to search and replace.

pinMode is our first function call. A function call tells the software to do something (either built into the language, or as we mentioned earlier, run something in a library). In this case, this calls a function named pinMode, which runs some software in a black box to set up the specified pin (in our case, pin 13) to be an output. The advantage of a function call is that it can be called with a different variable (for example, any pin number in this case) and that it runs the same way every time.

Driving Your Mother In Law Loopy

Now that we've told the Arduino how we'd like to use our pins, we can move on to the main course—the loop() section of the code. Here's where we take control of the dynamic parts of our software.

In our on and off LED first example, our loop includes four different lines, with two other function calls. The calls we use here are digitalWrite() and delay(). For now, we're using this code to blink the LED on and off. In later examples, we'll add sound, enough to drive your mother in law loopy herself.

digitalWrite() is used to set our pin (pin 13, which we're using a shortcut to specify, using the variable LED) to either HIGH or LOW. In the case of the Arduino, digital HIGH is 5V, digital LOW is 0V. We've now made the transition between the world of software, and the world which we know and love of hardware.

delay() is used to do just that in the code—wait for a specified number of milliseconds before going on to the next line. In our code, we set the LED high—wait one second—set the LED low—wait another second—and keep doing that forever in our loop.

This is an appropriate place to now load up the first example: LED On and Off, into your Arduino—and hopefully, get it to successfully compile and loaded into your Arduino.

The Second Arduino Project: "C" Some Simple CW

About here is where the observant will say: AHA! Why couldn't we change those delay() statements and instead of mindlessly blinking the LED on and off—let's set those delays to the right amount of time to send some CW?

To do this, we are using the same two functions we used for our LED—digitalWrite, and delay—but now adjusting our delay to make this match what you might see for CW. In CW, it happens that you can translate words per minute into milliseconds per element, by using the formula milliseconds per element = 1200 divided by WPM. Arbitrarily choosing 12 wpm, that means the amount of delay we need to make a dot is 1200/12 = 100 milliseconds.

So, to send a dot using our code, we need to set the LED high for 100 milliseconds, and then wait for another 100 milliseconds after the dot. See Figure 11.

Using that same math, as we all know, a dash is supposed to be exactly three times the length of a dot. In our case here, that is 300 milliseconds. By setting the LED high with digitalWrite and waiting for 300 milliseconds—and then again waiting 100 milliseconds for the pause between the dash and the next element—we can send a dash. See Figure 12.

So, now that we know how to send a dot and a dash, we can put those together and in our example here, send out a C (pause) C (pause) and so on. We are doing this in the first example by just copying and pasting the code; however, the "correct" way to do this (which we will show you in our next article) is to create our own function to send a dash or a dot. In software, anytime you repeat the same code over and over, it should be a function. However, for our example and to help you learn the software, we've shown this copied and pasted in Figure 13.

OK class, for your homework write the Code for the letter "Q" using these same steps to send "C." You can check your homework at the http://jessystems.com website under www.jessystems.com/arduino_build.html

Next Steps: Hearing and Keying CW With Arduino

At this point, you now have some Arduino software which you can load and blink any CW you want to by compiling and uploading your code. Our next article will cover some enhancements to this, namely, making it much easier to send a dot, dash, and characters using function calls—and an enhancement to not only blink an LED, but vary CW speed and hear CW on the Arduino. We will even use the Arduino as an actual automated keyer that, in addition to keying a transmitter, can generate random call signs and text for code practice.

Stay tuned!

—de KK6FUT and N6QW

Resource Links

The Arduino craze has caught on like wildfire and so there is a lot of information floating around the internet and shame on us if we forget to mention the hundreds of youtube videos. We believe the homebrew beer dispenser which first checks to see if you are old enough to drink and then dispenses homebrew of another variety may still be active.

That said, use caution in evaluating the information as some of it may have been developed for a variant of the Arduino and may not work on your Uno R3. We are recommending two resources one of which is the Arduino website which can be found at http://arduino.cc/. Make a special note that there is not a dot com after Arduino. An excellent text is the second resource which is authored by the co-founder of the Arduino and is entitled *Getting Started with Arduino* 2nd Edition, by Massimo Banzi. This short booklet is available at sources such as Barnes and Noble, Amazon and Radio Shack. The price is about $15 USD.

■■

QRP = Doing More With Less!

The Poor Ham's Scalar Network Analyzer

Nick Kennedy—WA5BDU kennick@gmail.com

I can't seem to start a talk or article without first mentioning that it's a great time to be a ham builder and experimenter. Availability of inexpensive components and modules, free software and a huge knowledge base available on the internet, both in static form and in consultations via discussion groups. OK, I got that out of the way. Onward to the Poor Ham's Scalar Network Analyzer (PHSNA).

In September 2013, Jim Giammanco, N5IB and Jerry Haigwood, W5JH announced via discussion group postings their collaborative project for a versatile measurement system integrating a DDS RF generator, an Arduino microcontroller board, and an RF log power meter based on the AD8307 chip.

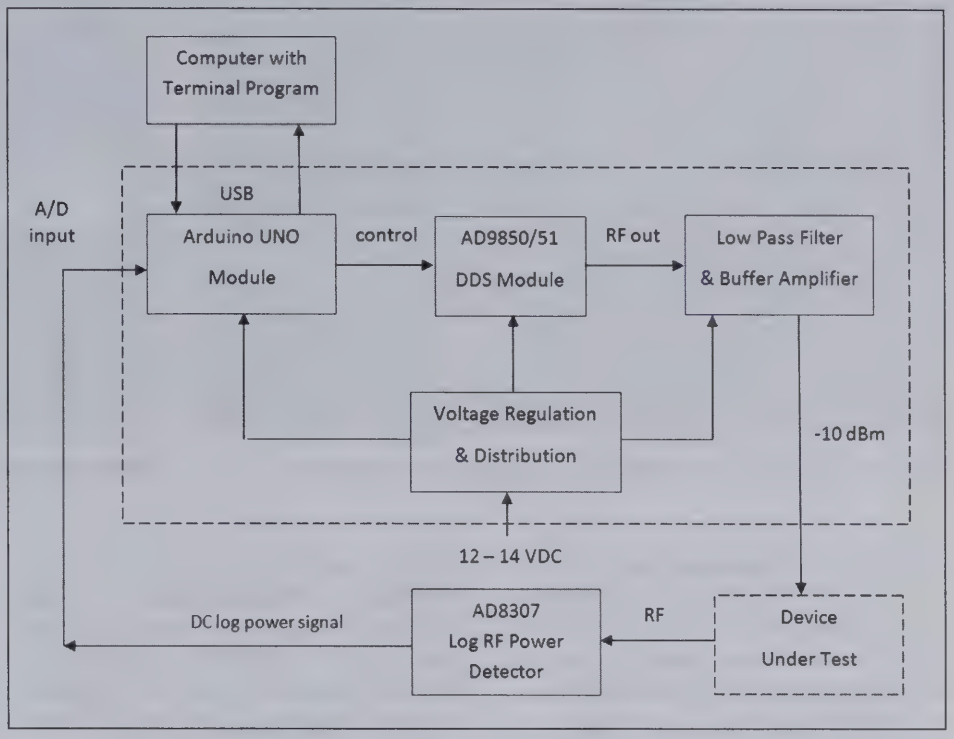


Figure 1—PHSNA block diagram.

What's in a Name?

In the original announcement post, the project was jokingly called SSNAFHU, for Simple Scalar Network Analyzer for Hams —Unveiled. We've standardized on PHSNA, Poor Ham's Scalar Network Analyzer, emphasizing the low cost of construction and because it's the name of the Yahoo Group. Lately I also hear SSNA for Simple Scalar Network Analyzer.

But the key term is "scalar," suggesting a modest reference to the fact that this isn't a Vector Network Analyzer (VNA). It gives the magnitude of gain or loss through a network, but not the phase shift. But I think we're seeing that magnitude only measurements can be quite useful.

What is it? What does it do?

The system is built around two off-the-shelf modules. Refer to Figure 1 for this discussion. First is an AD9850 DDS board which includes the clock module and other components necessary to make a complete DDS RF generator, excluding controller. Next is an Arduino board which will provide user interface communications, control of the DDS, and necessary ADC conversions on the signal from the log power meter.

The heart of the project is a small (2.75" by 4") motherboard onto which both modules are mounted. The board has 0.1" female headers on both faces to accommodate matching pins on the DDS and Arduino modules, putting it in the middle of a three board stack. The board makes the required connections between the two modules, plus provides voltage regulation, post-DDS filtering, an amplifier stage, and attenuators to control level and keep impedances constant. The DDS and Arduino modules and their motherboard reside within the dashed rectangle of Figure 1. Figures 2 and 3 show the DDS and Arduino sides of the board, respectively.

Thus far, we have a functional and useful RF signal source. To turn this into an analyzer we need an RF detector. The project uses a version of the circuit published in 2001 in *QST* by Wes Hayward and Bob Larkin [Ref. 1], with several variations published in succeeding years. It uses the amazing AD8307 chip which can measure RF signal strength from about –80 dBm to +15 dBm. Originally, the project was going to let participants be on their own for this component, but then Jim found that he could squeeze the circuit onto the standard production board size when he did the layouts, and got the OK from Mr. Hayward to publish his circuit on the PHSNA Yahoo site. Because of its extreme sensitivity, the log power measurement circuit needs to be in a separate enclosure and its board is separated from the main board. Users can include an analog meter to make it a standalone instrument as in the original article, or omit the meter and just let the Arduino convert the voltage output to a dBm reading.

Which brings us to the "what does it do?" part. Again turning to Figure 1, we see the system in action, sourcing a signal through a Device Under Test (DUT) (crystal, filter, amplifier, attenuator, etc.) and then into the log power detector, which sends a DC voltage output proportional to the log of RF power back to the Arduino. The Arduino converts that signal to a number representing RF power in dBm and reports it back to the user via serial / USB port. By sweeping the DDS over a desired range of frequencies, we can create an array of data showing the response of the DUT and display it graphically as seen in the lovely plots we've included in the article.

As hams, we know the value of seeing the response curves of our filters: lowpass, highpass, bandpass, IF, and other networks. Also, we can characterize individu-

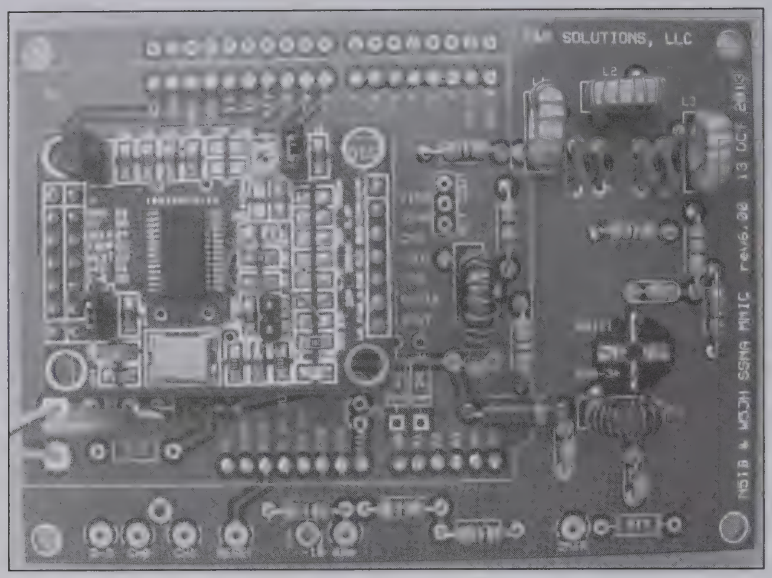


Figure 2—Main board with DDS, filter and post amplifier.

Figure 3—Main board from the Arduino side.

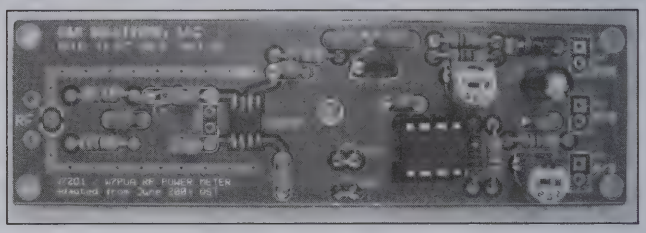


Figure 4—Log power meter board.

al crystals and use the parameters we've measured to design and build our own crystal filters. And we can see how "broadband" our broadband amplifiers actually are. Add a simple outboard bridge and we can check the SWR of our antennas.

Board Details

The power supply section requires 11 to 13 VDC input and uses an LM7805 regulator to provide +5 VDC for the Arduino and DDS. The full supply voltage is required for the post-DDS amplifier. Also provided is an adjustable LM317L regulator circuit to allow setting the ADC reference voltage used by the Arduino to the desired value.

The DDS module includes a filter, but it is made from tiny SMT components of questionable Q value, so a higher quality replacement filter using toroidal inductors is included in the board layout. It's flat out to 33 MHz. (That's for the AD9850 version. The AD9851 version will allow going beyond 6 meters.) There are resistive attenuators before and after the filter and after the amplifier to maintain 50 ohm terminations for the filter and assure a 50 ohm generator output resistance. These also set the target output level of approximately –10 dBm. The basis for this choice is to allow driving crystals at a proper level.

What about that amplifier? This is an evolving project and two versions were designed with separate board runs made for each. The first was based on EMRFD Figure 2.57 and used a 2N5109 transistor providing about 16 dB of gain. Another version uses a MMIC amplifier. This might be a good choice for anyone choosing to substitute an AD9851 module for the AD9850 originally proposed, taking the maximum frequency from about 30 MHz to about 60 MHz. I built the 2N5109 version and adjusted the amplifier and attenuator chain to get about +8.5 dBm output.

When putting it all into a box, these connectors and controls are needed: An RF output jack, typically BNC. A log power signal input jack. A +12 VDC power jack. For serial / USB communication and programming the Arduino, a cutout is needed to allow access to the Arduino's USB jack. My Arduino came supplied with a USB cable. A USB to serial driver makes it look like a serial port within my PC. In addition, a reset pushbutton for the Arduino is a good idea so you don't have to interrupt power to re-start the program.

Not Too Complicated So Far, eh?

The design for the log power board follows the Hayward / Larkin version (Ref. 1) fairly closely. It contains a battery, 5V regulator, the AD8307 chip, and a following op-amp with adjustable gain, plus an input compensation circuit giving it a wide bandwidth of over 500 MHz. Jim made boards for both DIP and SOIC versions of the AD8307. A number of suitable op-amps have also been proposed in lieu of the original LM358, so use your junk box. A unique feature of the board is inclusion of ground foils placed to allow building a copper "Quonset hut" shield over the AD8307 chip. This is optional and since my enclosure for this board is very RF tight, I did not include it in my build.

Calibration pots will allow scaling the maximum output of the log power board to match the ADC reference voltage set in the PHSNA board.

Controlling it—The User Interface

No display, no keyboard and almost no switches. The simplicity of this design comes in part from having the user interface made via a serial terminal. It seems almost archaic, but even in this modern age we can still find serial terminal programs to run on our PCs and talk to the Arduino via its virtual serial port. The Arduino spools out a menu when booted and waits for the user's input. I chose term232.exe as my terminal program. It's free, small and simple and runs fine on my laptop under Windows Vista. When working in the Arduino IDE environment, one can also just pull up its serial monitor and talk to the PHSNA from there. This project is a hacker's delight though. One user has already added an LCD to his PHSNA box showing current frequency and dBm reading.

The Software

Here's another place where hackers can have some fun. The PHSNA software is completely open source, so if you like to program, dive in. The software was rolled out with two functions. The SNA function scans a user specified range and step size

and outputs to the serial terminal the current frequency and the level in dBm read back for each frequency. This information is transmitted in the "comma delimited" format that can be picked up by Excel or other programs for graphing. Just do a "capture" with the terminal program and you've got your data file.

The second function is the Generator function. The user specifies a frequency and the DDS goes there. A dBm reading is also displayed. Arrow keys and adjustable step size allow moving the DDS around and seeing the change in response, if the AD8307 board is connected.

I jumped on the software bandwagon and added several functions. Some of them were developed mindful of users who don't want to alter program code, or even "burn" an existing program to the Arduino. I added the ability to calibrate the DDS's clock to a standard (such as WWV) and to determine the AD8307's slope and intercept constants used to convert the ADC reading to dBm. Also the ability to set and/or change the start-up frequency of the DDS was added. All this information is saved to EEPROM and read at each start-up, so there's no need to "hard code" it into the source code and burn a custom version.

I initially did the slope and intercept using two points of data, but Jim pointed me to a statistics site that gave a method for calculating a best fit slope and intercept from a set of multiple data points, so I added that capability to the routine. SWR measurements using the return loss bridge became a separate menu item.

I also added ten memories accessed with a keystroke (0 through 9) to act similar to band switches. And finally a "Scan" function simply sweeps the DDS over a specified range and repeats indefinitely.

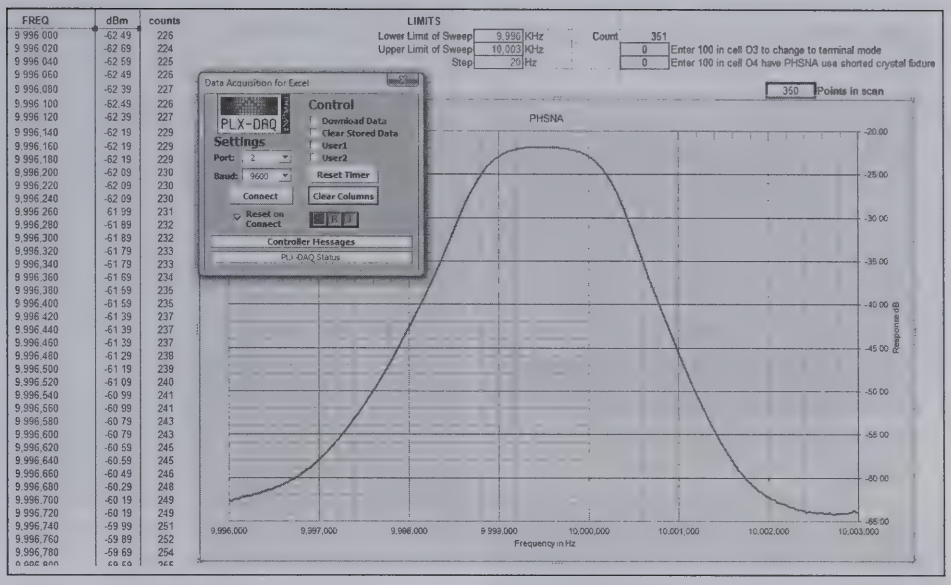


Figure 5—Spreadsheet running PLX-DAQ link to PHSNA.

Normalization and Frequency Compensation

Often when plotting the response of filters, you don't care about the actual dBm numbers but instead want zero attenuation to be graphed as a 0 dB reference and everything goes down from that. This is where normalization comes in. The software can automatically normalize readings so the reading with no losses will be 0 dBm.

In addition, there will usually be a slight falling off in RF level from the PHSNA as frequency increases. The user just wants to see amplitude changes caused by his DUT, not by the RF generator. The software also can address this, using a 5th order polynomial equation to flatten the reported response. This hasn't been automated (yet) but Jim has placed a detailed description on how to get Excel to compute the coefficients from a "self scan" of the PHSNA in a PDF on the Yahoo site. I added a function to allow entering these constants from within the program which then saves them to EEPROM so no editing of source code is required.

For those who do want to edit source code though, note that the IDE is a free download and no external programming hardware is required to program the Arduino—just plug in the USB cable and go. Here's what's on the start-up screen:

```
Current reference clock frequency is:
  179987712
Mode flag: Normal Mode
Retrieved:
slope = 0.10110  intercept = -84.62
DDS is running on: 7040000 Hz
  AD9851 mode
PHSNA Standard rev 3.01

Select:
  0 - Restore this menu screen
  1 - SNA Functions
  2 - Generator Functions
  3 - Return Loss Bridge & SWR
  4 - Measure Crystal Parameters
  5 - Memories
  6 - Scan
  * - Options & Calibrations Menu
```

And here's the separate menu for setup and calibrations:

```
Choice:
  A - Calculate or enter AD8307 slope /
      intercept
  C - Curve fit polynomical constants:
      View/Enter/Clear
  D - Calibrate DDS reference frequency
  P - Change start-up mode to PLX
      (Excel) or terminal
  S - Set Start-Up Frequency
  M - Toggle AD9850/AD9851 modes
  Q - About PHSNA
  $ - Re-display menu
  ^ - Back to main menu
```

PLX-DAQ Interface to Excel

Option 6 requires some explanation. Jack Generaux, WØFNQ found an Excel macro widget called PLX DAQ that's freeware from Parallax, maker of the Basic Stamp chips. This add-in gives Excel the ability to communicate via serial port, importing data from external hardware. Jack customized the PHSNA's Arduino software so it would ask for upper and lower limits and step size from specific Excel cells, then proceed to scan that range and send the frequency and dBm reading for each point to back to Excel where it could be plotted. This avoids the need for a terminal program entirely. Figure 5 shows PLX-DAQ in action. The data for the filter plot was imported directly into Excel from PHSNA using the PLX-DAQ interface.

I'm highly impressed with PLX-DAQ

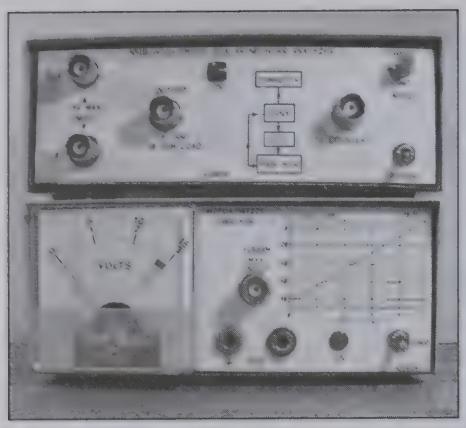


Figure 6—PHSNA and power meter by KG9DK.

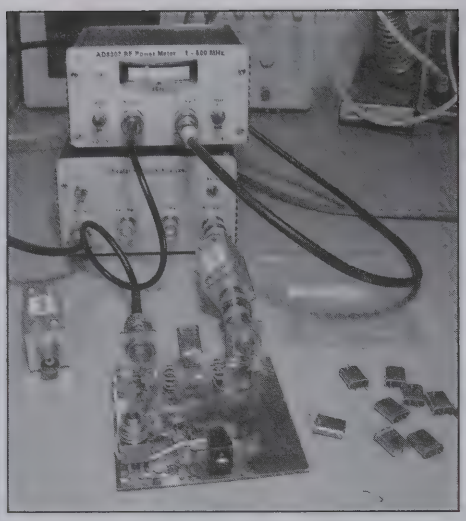


Figure 7—WØWPE's PHSNA and meter at work testing crystals.

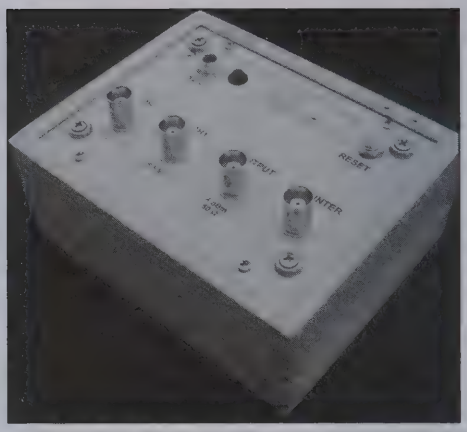


Figure 8—N5IB's PHSNA in a custom wood box.

Figure 9—WA5BDU's log power circuit in box.

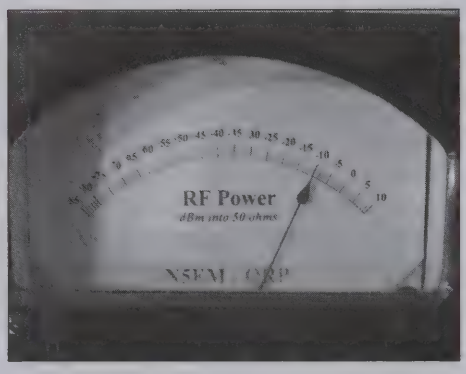


Figure 10—N5EM's classic meter movement with a custom scale.

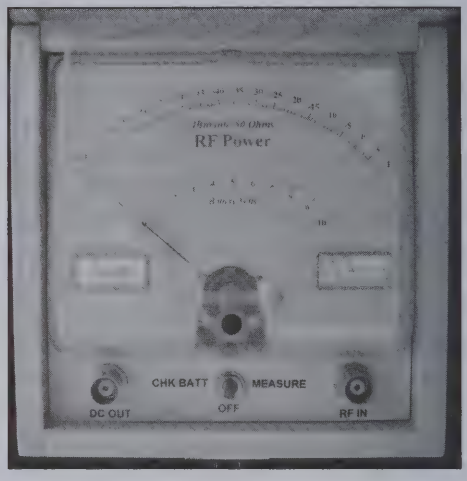


Figure 11—N5IB's meter with custom scale and box.

and decided to integrate it into the mainstream program so instead of having an "either/or" firmware configuration, the user could toggle between "terminal" and "PLX DAQ" modes as desired. You can manually tell it to switch modes, but it can also detect how it's connected and swap automatically.

Crystal Scanning Function

Finding the 3 dB bandwidth of crystals and their series resistance is required to determine crystal parameters Lm, Cm and Rs for use in filter design. One can easily go through tabulated or plotted data and find the bandwidth. and the Rs value can be found by resistor (potentiometer) substitution. This was all outlined by Jim Kortge K8IQY in a couple of influential AmQRP articles (Ref. 4) and by Hayward and Demaw before that. Then you crank through the math with your calculator or spreadsheet to determine the parameters.

I thought it would be a natural application for software to automate this process and wrote routines that automatically find the resonant peak and loss at that point, as well as finding the upper and lower half power points. With this information, the Arduino can (and does) crunch the numbers to get a crystal's model parameters (including Rs) using standard formulas, and do it in a jiffy. Now you can take a stack of crystals and find their motional parameters in a small fraction of the time it took previously. You could easily do one crystal per minute once you get rolling.

How Much Does it Cost?

We'd all like a workbench full of sophisticated test equipment, but price is important. I can't tally up what a complete system would cost since it varies so much. But I can say approximately what I paid for the major items. I made good use of the eBay / China supply chain when possible. These prices are postpaid and are what I paid. Others paid more or less.

Arduino UNO	$12.30
DDS AD9850 (30 MHz)	$6.88
PHSNA board set	$6.50
(one for the DDS/Arduino and onefor AD8307 power meter)	

The board set is not currently available as the last run is sold out. However, if evidence of sufficient interest is shown, the organizers of this project, N5IB and W5JH, have agreed to run another board set in the near future. If you are interested in the project, the best approach is to join the PHSNA group on Yahoo and tell the organizers of your interest. Likely cost for a board set is about $15 plus shipping.

Of course you have to populate the boards with the usual resistors, capacitors, regulators, connectors and toroids, and provide enclosures. I have a pretty deep

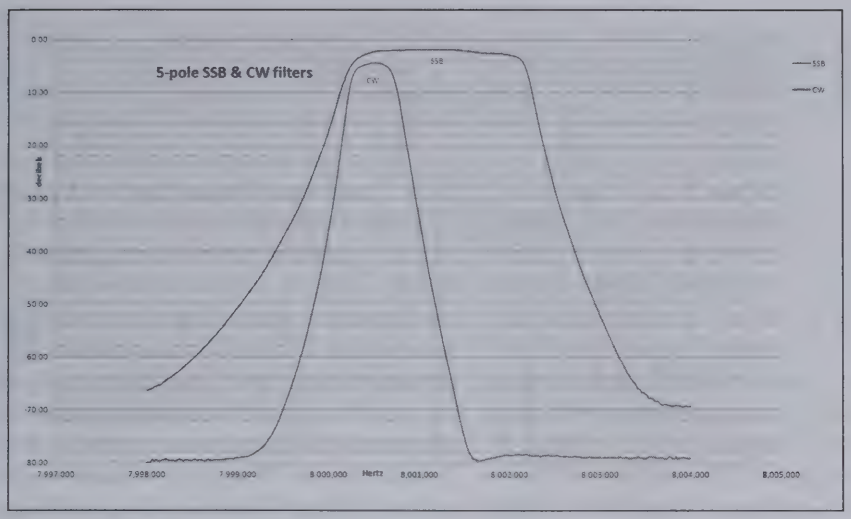


Figure 12—Passband plots for 8 MHz SSB and CW filters.

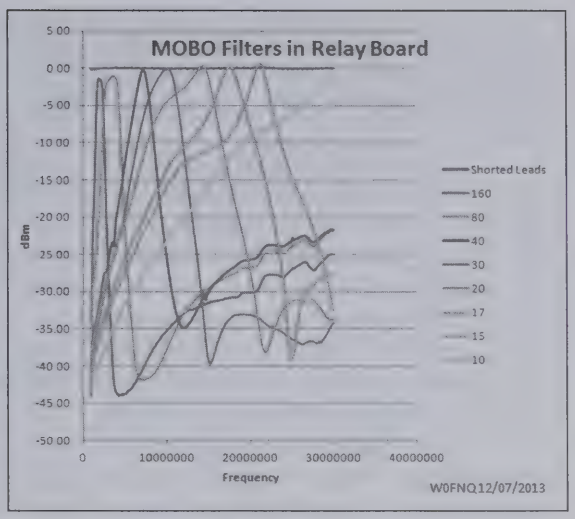


Figure 13—Multiple bandpass filter plots.

junk box but others might have a pretty good shopping list. The AD8307 chip could set you back $12 or so, or maybe you could get a free sample. I went to eBay and bought ten (10) of them in the SOIC-8 package for $9.50 postpaid, less than a dollar apiece.

On the PHSNA site is a spreadsheet BOM with info on where parts can be purchased. It includes photos of the Arduino and DDS boards, since you want to buy the correct form factor. An eBay search for "AD9850 module" or similar is suggested. Suggested vendors on eBay include "chip_partner," "chipworld," and "survy2014". Compare the hits you get with the photo in Figure 2.

Builds and Boxes

As you see from the photos, there are some real craftsmen in the group. A PHSNA in an ugly "repurposed" box (like mine) can work well too, but we'll focus on the pretty ones here. Figures 6, 7 and 8 show implementations by KG9DK, WØPWE and N5IB. I show my own log power circuit enclosure in Figure 9 as an example of one without a meter movement. If you do use a meter, it's hard to beat the beautiful old Weston movement with custom scale by N5EM shown in Figure 10. He used the Galva application to create the scale. Likewise, look at N5IB's beautiful meter and custom enclosure in Figure 11.

Again, two boxes are required. The one for the DDS / Arduino "sandwich" doesn't require much shielding but the one for the AD8307 log power measurement circuit should be in an RF tight box.

Getting Down to Business…

This is the fun part—actual measurements. To measure filters and other networks just put the DUT in circuit per Figure 1 and run a plot. You can save plotted data to a CSV file for plotting by Excel or other plotting programs, or import directly into Excel with PLX-DAQ.

In Figure 12 you see that I plotted the response of CW and SSB bandwidth filters on the same graph. This view will help determine the best placement of the BFO injection for each mode.

Figure 13 shows plots of eight separate bandpass filters in a WØFNQ project.

The PHSNA system is great for plotting the SWR of antennas when used with a return loss bridge. Figure 14 shows a plot I did of my tribander on 20 meters. The return loss bridge (RLB) is a simple device, discussed later.

You needn't limit yourself to checking passive devices. I used the PHSNA to plot the gain of a homebrew 35 dB gain broadband utility amplifier over the range of 1 MHz to 60 MHz. Just put a big attenuator at the input end so as not to exceed the AD8307's measurement range or drive the amplifier into saturation.

When doing crystal characterizations, the numerical results tell more than plots. Table 1 shows tabular data captured from PHSNA in testing a set of several crystals. This data is all you need to design your own crystal filters using any of a number of popular programs available free.

Accessorize!

You can do a lot with just the PHSNA and log power meter, but there are some other gadgets that will extend its usefulness.

Power Level Calibration

For most measurements, the relative levels of two powers are all that matters. That's what decibels are all about, after all. So we mostly need an accurate slope measurement on the log power measurement circuit. But some of us want to know the absolute power level being measured

```
Press 'Y' to test another w/same parameters,
Press other key to return to menu
Assign/change crystal ID (Y/N)?

ID#,  F_peak, loss(dB), BW, Rs,  Cm (pF),   Lm (mH),    Q
JH01, 4432251, 4.25, 74.0, 15.8, 0.0147079, 87.667694, 154899
JH02, 4432271, 5.06, 79.0, 19.7, 0.0143055, 90.133056, 127162
JH6, 4432243, 9.91, 136.0, 53.2, 0.0140858, 91.540275, 47899
JH9, 4432246, 4.55, 75.0, 17.2, 0.0143952, 89.572540, 144944
JH10, 4432308, 3.34, 66.0, 11.7, 0.0145663, 88.518142, 210561
```

Table 1—Crystal test results in tabular form.

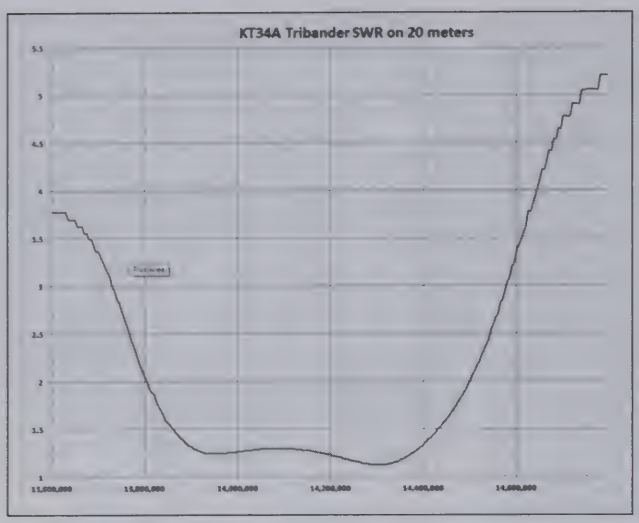


Figure 14—SWR plot of a KT-34A tribander for the 20 Meter band.

and/or being sourced by the PHSNA generator. You can do adequate calibrations with things like compensated diode detectors or oscilloscopes to establish a reference power level. Or you might use a 1 watt QRP transmitter and run it through the 40 dB tap described in the Hayward / Larkin article log power meter article [Ref. 1].

But some of us wanted to get fancy and tried a simple but accurate calibration source initially described by Bob Kopski K3NHI in the Jan/Feb 2004 issue of *QEX*. It uses a common computer clock module as a source. The calibrator and an extension of it are described in VE7BPO's popular QRP Homebuilder website (Ref. 2). Speaking of accessories, a step attenuator is nice to have for calibration and slope determination. Separate chainable attenuators work well too. I built the Kopski standard and the VE7BPO sine wave source that calibrates to it and now feel like I have a pretty accurate indication of true power level.

Crystal (and other) Measurement Jigs

You can just stick a crystal in between the PHSNA's RF out and the AD8307's input and measure it in a 50 ohm environment, but you're going to want some kind of socket or grabbers. So while you're at it, just make a dual 4:1 transformer arrangement to put the crystal in a 12.5 ohm environment for better accuracy. This was described in the K8IQY series [Ref. 4]. In Figure 7 you see WØWPE's set-up using the transformers of his K8IQY circuit for crystal measurements with PHSNA.

Return Loss Bridge

A return loss bridge (RLB) is a simple device consisting of three 49.9 ohm 1% resistors and one ferrite transformer plus three BNC jacks. But it expands greatly what you can do with the PHSNA, notably read the SWR for your antennas. But, a good 50 ohm match can also be important in other circuits such as filters and amplifier inputs. Jim and Jerry came up with a beauty and put it out as a kit including a Hammond box and a circuit board with holes that align perfectly with the BNC pins—no leads. Well worth having. RLBs are easy enough to build on your own if you want to go that route.

Mutations, Bifurcations and Tangential Developments

With a popular "open source" project, it's hard to keep up with developments. Hardly a day goes by that I don't see some new customized features added by a user. At least one person has added a text display with I^2C interface and added coding to the Arduino program to send it frequency and dBm information. Just yesterday (as I write in February) George N2APB and Dave AD7JT showed preliminary photos of a hand held terminal for the SSNA that accepts a keyboard connection and has a color graphics display. No computer required! A run of kits is expected.

Jerry, W5JH is working on a "measurement receiver" to scan and quantify harmonic levels from an RF source.

I'm personally working steadily on a stand-alone Windows application to interface directly with the PHSNA using Visual C#. The idea is to have the PC do all the hard work and just have the Arduino accept frequency information and return ADC (log power) information. Ideally, the program will also have graphing routines so no outside graphing program will be needed.

Where's the Schematic?

Really, I'm not holding anything back. But the project has a number of variations in configuration. Two or three different DDS modules, plus some are using NJQRP / AmQRP DDS-30 and DDS-60 boards. Going to 60 MHz changes the filter component values. There is also a version with a 2N5109 post amplifier and another with an MMIC amplifier. You get the idea. But the schematic diagrams and other technical information are presented in depth on the PHSNA Yahoo website. If you are interested in giving it a shot, sign up and take a look. Jim has also produced a number of illustrated guides in PDF format to help the user build and use the various components. You'll also find a lot more photos, graphs and other information from group participants.

Acknowledgements

We thank Terry WB4JFI, Bill W2EB, Leon G1HSM and Tracy N4LGH for providing some excellent information on working with the inexpensive DDS modules being sold by offshore electronics vendors. This allowed Jim and Jerry to move forward and make the PHSNA project a reality.

Conclusions

I believe the PHSNA is a project that results in an extremely useful and versatile RF measurement system at low cost and only moderate building complexity. I hope readers will see it the same way. We'd love to have more folks jump in and give this project a try.

References

1. "Simple RF-Power Measurement," by Wes Hayward, W7ZOI and Bob Larkin, W7PUA, *QST* June 2001.

2. QRP SWL Homebuilder: http://www.qrp.pops.net/RF-workbench-5.asp

3. PHSNA discussion group: https://groups.yahoo.com/neo/groups/PHSNA/info

4. "Tools and Methods for Measuring Crystal Parameters," by Jim Kortge, K8IQY, NJQRP *Homebrewer* Issue #9

Operating Low Power on the Low Bands (160, 80 & 40M)

Jim Rodenkirch—K9JVW rodenkirch_llc@msn.com

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Background: I had never operated on 160M prior to 2010 but did operate on 80M back "in the day" when I was a newly licensed Conditional Class operator (late 50s). However, over the years, I gravitated towards the higher bands—20, 17, 15, 12 and 10 meters—due, mainly, to limited lot size where ever we lived. I have accumulated 278 DXCC worked/confirmed with 100 watts or less, mostly via CW mode, across all bands, over the years while always employing dipoles or vertical antennas and yes, I enjoy chasing those remaining 62 entities. However, over the past three years or so, I find myself bored with re-working DX while waiting for those few occasions when a "new one" became available via a DXpedition or the occasional band opening.

I did become enamored with QRP/low power operations in 2010, courtesy of Steve Weber and his line of small, compact QRP kits. I acquired an ATS-3B and ATS-4, added a K1, a Wilderness Sierra and a Rock Mite or two and started focusing on operating QRP. I rid myself, within the past year, of all but one Rock Mite, one KD1JV 160 meter project rig, one KD1JV Tri-Bander and an HF Packer Amplifier. That HF Packer Amp outputs around 30 - 35 watts and the reason why I state "low power" in the title of this article and not QRP—once in a while, the bands aren't all that conducive for QRP power and 30 watts can be the tipping point for adding a new DXCC entity.

How I got started in low power ops on the low bands: During the summer of 2011 I stumbled across a website hosted by IW5EDI that spotlighted a "160 meter antenna for a small lot." The information and picture (see Figure 1), supplied by K5CBL, intrigued me. Go here for the write up: http://www.iw5edi.com/ham-radio/?a-160-meter-antenna-for-small-lot,105.

I had read, extensively, on the trials and tribulations associated with operating on 160 meters (an excellent resource for all things technical and operational is the Top Band reflector—join here: http://www.contesting.com/FAQ/topband)—so I was itchin' to try something new, as long as I could operate CW! Thinking, "why not," I assembled the "small lot" antenna, found five 75 foot wires to use as counterpoises/radials, erected the antenna, temporarily, outside my shack and ran the five counterpoise wires along the back patio deck and out on the front yard. I connected the antenna to my venerable Icom 735, keyed it up and found the SWR, without a tuner, was 1.3:1! It was "Miller Time!" Cranking the power down as low as it could go and inserting a quickly assembled 2 dB in-line attenuator, I entered the 2010 CQWW 160 meter contest as a QRP entry. At the end of the contest, I had garnered 182 QSOs, 37 multipliers (mults) and three (count 'em, THREE) DXCC mults—I was HOOKED!!! To work 182 QSOs with that temporary lash-up setting outside my shack, on a band KNOWN for antenna requirements that include long and tall

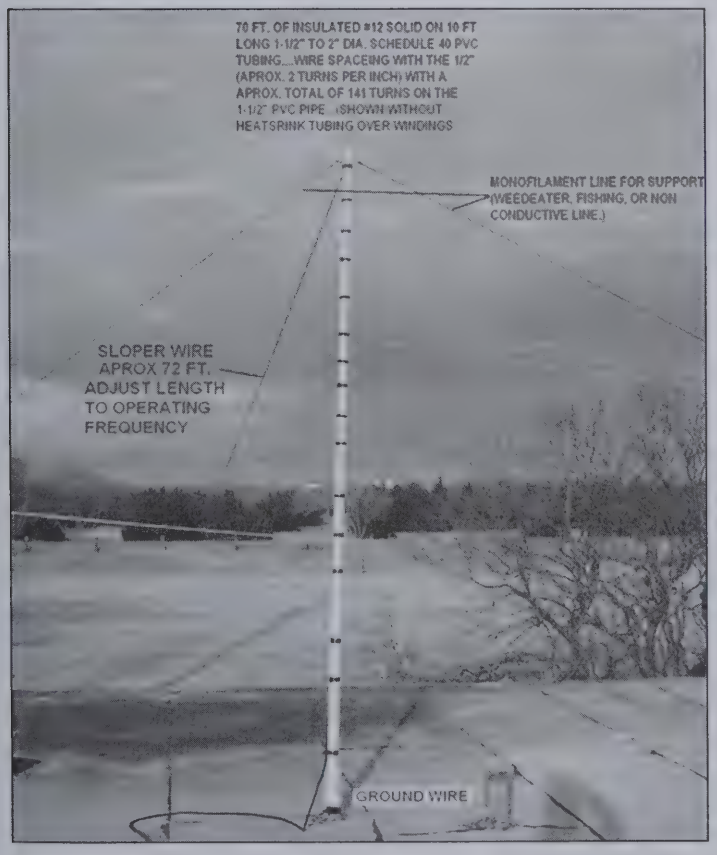

70 FT. OF INSULATED #12 SOLID ON 10 FT LONG 1-1/2" TO 2" DIA. SCHEDULE 40 PVC TUBING....WIRE SPACEING WITH THE 1/2" (APROX. 2 TURNS PER INCH) WITH A APROX. TOTAL OF 141 TURNS ON THE 1-1/2" PVC PIPE (SHOWN WITHOUT HEATSRINK TUBING OVER WINDINGS
MONOFILAMENT LINE FOR SUPPORT (WEEDEATER, FISHING, OR NON CONDUCTIVE LINE.)
SLOPER WIRE APROX 72 FT. ADJUST LENGTH TO OPERATING FREQUENCY
GROUND WIRE

Figure 1—A 160M antenna for a small lot.

Figure 2—West view of the vertical antenna and 6"x6" mounting post

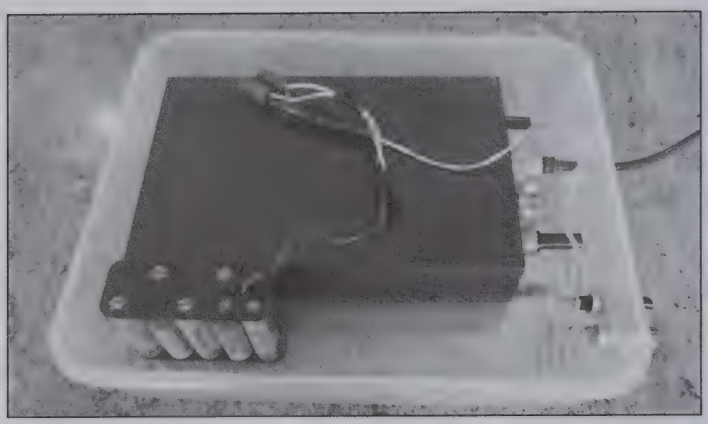


Figure 3—Auto tuner, weather resistant enclosure and battery holder for DC power.

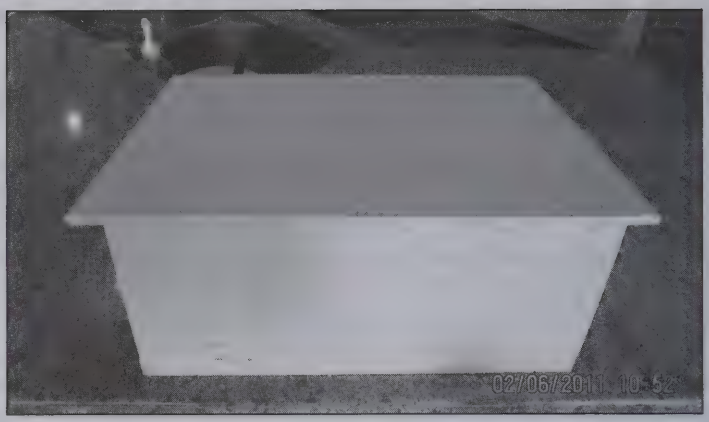


Figure 4—Auto tuner "doghouse" that will contain the tuner and battery box.

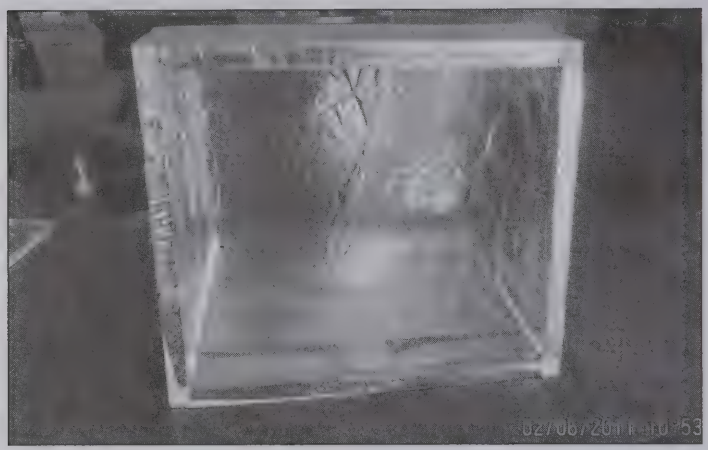


Figure 5—The doghouse is foil lined for RF shielding.

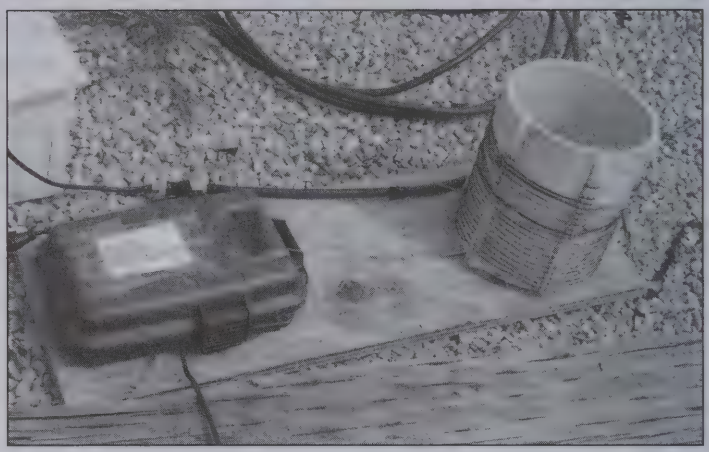


Figure 6—Relay enclosure box and 160M loading coil.

inverted L or vertical antennas and oodles of long radials/counterpoises in order to achieve success at making QSOs, "rang my bells"—even the XYL could tell my commitment to operating on Top Band and low bands had intensified.

Recalling my fun times on 80 meters back in my early days of ham radio, I started thinking about operating on that band as well. However, there were two "problems" with the small lot 160 meter antenna—it didn't tune up on 80 (the antenna tuners I owned did not like that inductive 70 feet of coil and it was temporary (wires lying on the back deck and across the lawn in the front yard tend to attract disapproving eyes from the XYL. A weekend... she's good with that. Much past Monday morning, not so good...). So, I had to find a spot on the property where I could erect a meaningful, i.e., efficient, antenna. It didn't have to be stealthy but it couldn't be an "in your face, 100' shunt loaded tower with multiple 1/4 wave slopers for 80 meters hanging off the sides," either; that was as much my requirement as the XYL's!

After perusing the Internet, the ARRL Antenna Handbook and many discussions with Terry, N6RY, who performed a lot of modeling analysis for me, I opted for a 43 foot vertical antenna system with three 25' wires sloping down from the top of the antenna at 45 degree angles. Not totally stealthy but decidedly not an "in your face" antenna and, with an adequate set of radials/counterpoises, tall vertical systems are one of the favorites for the low band crowd of operators; equally important, the shape and length of my property screamed, "Get a vertical and associated radials planted!"

Purchasing a commercial product didn't cut it for me—isn't Amateur Radio ALL about muckin' about with antennas… trying this, trying that?! So, I found a spot about 60 feet away from the end of the house where the shack is located and decided to "roll my own." The site sets on a severely sloped portion of our back yard (see Figure 2) but access to the antenna's base was easy to set up.

I wanted to operate on more than "just the low bands" occasionally—I still like adding a "new one" to my DXCC total—but I don't have the luxury of employing open wire feed line. So, I knew I'd be using coax and, thus, would need a remotely controlled antenna tuner at the base of the vertical. I found a used LDG Z11ProII which was more than adequate for my maximum output power of 30 to 35 watts; I housed that inside a water-resistant plastic box from Bed Bath and Beyond and a "dog house" to blunt the outside elements as much as possible. I wound a loading coil for 160 meters as I found out, via some modeling analysis completed by Terry, N6RY, that even with top loading wires the auto tuner would struggle to find a match. I employed a DPDT relay inside a water proof box, controlled remotely from the shack, to "insert" the top Band loading coil between the auto tuner and the base of the antenna. See Figures 3, 4, 5 and 6 for the foil lined "dog house," the water-resistant

plastic box from Bed, Bath and Beyond and the relay enclosure.

The aluminum tubing for the vertical was purchased from DX Engineering and Texas Towers. The aluminum used was type 6063-T832. At the base of the antenna, the diameter of the aluminum was 2 inches, graduating to smaller diameters at the higher portions of the vertical. A 6" x 6" 10 foot post was inserted three feet in the ground and a 2" x 6" inch board was mounted so the base of the vertical could be mounted to it; the board is hinged at the bottom so I can lower the antenna for repairs. See Figure 7.

Purchasing and running 100' of LMR-400 coax was easy. Installing the radial or counterpoise field was the final piece of the effort because the ground component of the vertical system really took some planning. More perusing of the Internet and papers/articles on ground systems drove me to one conclusion—discussing radials and counterpoises is like discussing religion! However, I waded through it all and, with some really lousy dirt in SW Utah and the modeling assistance of Terry, N6RY, I opted for elevated radials over buried or "on the ground"; elevated radials for me were easy to install. Close to 80 radials with 20 or so in each of the four quadrants were installed, but geographic constraints limited the length of the North and South wires (25' wires north and south); East and West wires had no such constraints. Modeling results said 50' wires east and west would do the job and the results of N6RY's modeling effort show acceptable patterns for 160, 80 and 40 meters (see Figures 8, 9 and 10).

A rough estimate of the cost for the system, including any "oops," came in at just under $200.00. The elapsed time required to complete this project can be described in months simply because this antenna system is the second iteration and I didn't plan the system well the first time around; e.g., the original site chosen for the antenna base didn't accommodate symmetrical N/S or E/W radials and the base aluminum tubing I chose wasn't sufficiently rigid (I didn't realize how strong the summer winds are that push along the wash below our property). However, I learned and this second version is holding up well, functionally and physically! See Figure 11 for a wiring scheme of the system.

Figure 7—The coil and switching system is located at the base of the vertical.

How well does the system work? Well, from a modeling perspective, courtesy of N6RY, we find that having equal-length radials deployed symmetrically, makes for very clean omni patterns on 160M-20M. On the higher bands, of course, the length of the vertical causes the main lobe to lift off the horizon, but in most cases there are still some lower angle lobes that would be useful, with gain usually around 0 to –5 dBi. On the higher bands, since the radials are all longer than 1/4 wavelength, they radiate horizontally polarized signals that make the pattern slightly bi-directional. The 160m pattern includes about 2 dB of loss in the loading coil (57.2 uH, Q=250). On 160m, Z is 8.587 –j0.0267 ohms and the bandwidth (2:1 at Z= 7.5 ohms) is about 15 kHz. Impedance on 80m is 17.3 –j235 ohms (no loading coil). In short, it does well on the low bands and works "ok" on the high bands.

An aside note: the narrow bandwidth that N6RY saw in his modeling results is what I experience—the auto tuner will retune if I QSY more than 20 kHz or so on 160 meters—that IS a good thing!

Finally, how does it "work"? Well, this second iteration was installed in May of 2012. Albeit anecdotal and remembering the first version wasn't nearly as efficient as the latest AND remembering my QTH is in SW Utah, I can provide these "data":

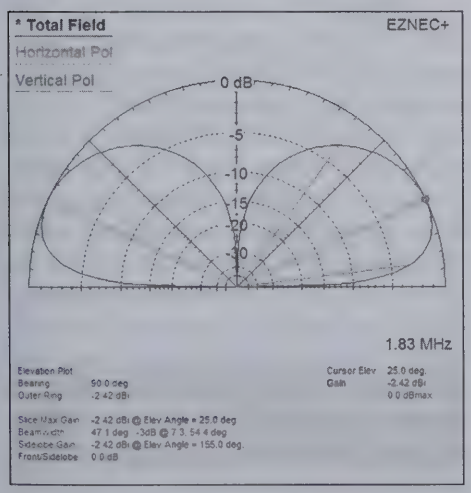


Figure 8—160M elevation plot.

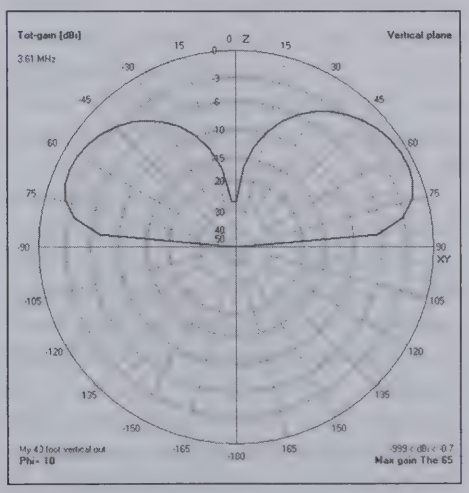


Figure 9—80M elevation plot.

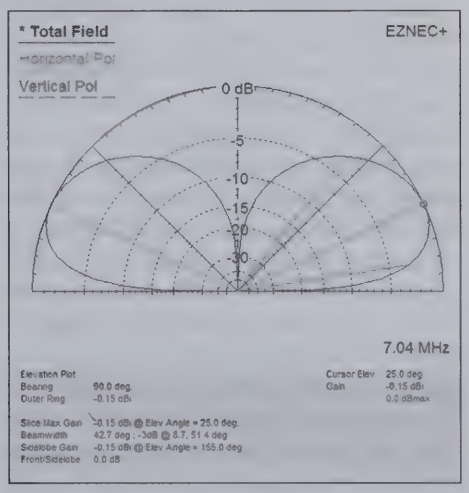


Figure 10—40M elevation plot.

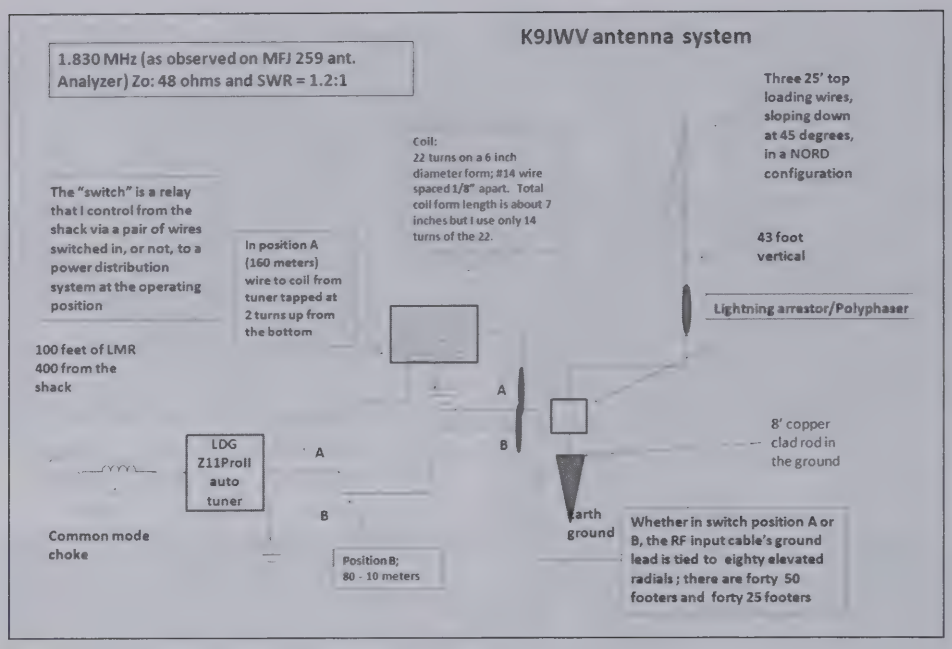

K9JWV antenna system
1.830 MHz (as observed on MFJ 259 ant. Analyzer) Zo: 48 ohms and SWR = 1.2:1
Three 25' top loading wires, sloping down at 45 degrees, in a NORD configuration
Coil: 22 turns on a 6 inch diameter form; #14 wire spaced 1/8" apart. Total coil form length is about 7 inches but I use only 14 turns of the 22.
The "switch" is a relay that I control from the shack via a pair of wires switched in, or not, to a power distribution system at the operating position
In position A (160 meters) wire to coil from tuner tapped at 2 turns up from the bottom
43 foot vertical
Lightning arrestor/Polyphaser
100 feet of LMR 400 from the shack
A
B
8' copper clad rod in the ground
LDG Z11ProII auto tuner
A
B
Common mode choke
Position B; 80 - 10 meters
Earth ground
Whether in switch position A or B, the RF input cable's ground lead is tied to eighty elevated radials ; there are forty 50 footers and forty 25 footers

Figure 11—System wiring scheme.

• I completed WAS QRP on 160 and 80 in Feb/March of this year (I started that effort in the fall of 2010 with the original vertical system but worked the majority with this second version).

• I have 16 DXCC on 160 (notables include VP6, C6, T30, HK, TX5, T32, JA, HL, RA, KH6, KL7) and 23 DXCC on 80 (notables include HL, 5W, E51, PTØS, NH8S, BU, JA, 3D2, TX3, RAØ) the majority being with QRP power (e.g., I needed 30 watts to work a VK on 160 on the 26th of August, 2013 at 1100Z—a "wow" QSO, in my book. W7 land to VK in August on 160 meters??? Oh yeah, it was Miller Time that afternoon!).

• I set a new record for Single Operator QRP, SSB on 80 meters for W7 during the 2012 CQWW WPX contest (bested the old record by nearly 4,000 points).

• I set a new record for Single Operator QRP, CW on 80 meters for W7 during the 2013 CQWW WPX contest (bested the old record by nearly 2,000 points; results haven't been posted yet for that contest but I know what my score is and what the previous score is).

The figures and numbers above indicate, to some extent, that my antenna system, albeit rudimentary by the standards of many "big gun" stations, is working well and, trust me, I am not bragging in the least, just providing some sort of measurement(s) that may entice you to leap in to the fray on the lower bands. My station, antenna system and operating skills don't match up with some of the current, outstanding QRP stations, e.g., VE3MGY and N7IR along with others and, most certainly, one can't begrudge the "big guns" who operate on 160 and 80 any of what they have or have accomplished. All of those engineering efforts, personal time and resources required to design and assemble 4-square transmitting antennas, Beverage antennas for receiving and the like, along with 100 watt and/or high power rigs, are to be applauded and admired. Yes, operating on 160 and 80 meters can be a grind; noise levels, spot propagation, auroral zones and rapid, rapid QSB (most noticeable on Top Band) are some of what one will experience. However, receiving a noteworthy signal report and a, "FB, Jim, great sigs for QRP and a vertical," scoring well in a contest or bettering a previous score validates my efforts and the assistance provided by numerous amateur radio friends.

In an "aside note" sort of way, I want to share some of the "Top Band disease," extracted from an N6TR write up that I know I have been infected with over the past three years include (note that some of these "symptoms" apply equally well to 80 meters):

- Desire to be on the radio at sunrise.
- Desire to be on the radio at sunset.
- Desire to be on the radio between sunset and sunrise.
- Desire to struggle for months to work a single station in a new country or, in my case with a modest station and antenna system, a new state.
- Never being satisfied with the antenna system and constantly trying new ones or, in my case, always walking out to the radial field to ensure all are still connected.

I thoroughly enjoy operating on the low bands with this antenna system—probably the best example, for me, of doing more with less. I hope this article encourages you to explore ways of erecting your own low band antenna. The effort can be challenging, particularly when one is saddled with less "antenna space" than one desires but the personal satisfaction and downright "fun" part of figuring it all out, ordering the parts/materials, putting the antenna up and then operating on the low bands is what "floats my boat." Personal queries via e-mail are solicited and encouraged. I am ready to field your questions and I have additional pictures and data that may be of interest to you.

About the Author

Jim received his Novice license in 1958 and his Conditional license in 1959. A military career with the U.S. Navy put his Amateur Radio operating time on hold but he retook the exams 25 years ago and thoroughly enjoys participating in this great hobby. A QRP, low band enthusiast and contester, Jim operates QRP in many contests and always attempts to work a "new one" with QRP power before turning the HF Packer amp on. He retired from the U.S. Navy in 1985 and, after working three years in the microwave tube industry, went to work for the Federal government as a Systems Engineer for the Navy, retiring from Civil Service in 2006 with 40 years of Federal service. He has a B.S. from Chapman University in Orange, CA. and a M.S. in Systems Engineering from Southern Methodist University (SMU) in Dallas, TX. An adjunct Lecturer at SMU, Jim enjoys teaching a graduate course in Systems Architecting for the Engineering, Management and Information Systems Department at SMU. He can be found on the low bands or reached via e-mail at Rodenkirch_llc@msn.com.

SimSmith Update

Ward Harriman—AE6TY ae6ty@arrl.net

Back it the winter of 2011, QRP Quarterly published an article titled, "SimSmith: A New Program for the Venerable Smith Chart." That article described computer program designed to allow the user to enter circuits and analyze their behavior using the Smith chart invented back in 1939. Here, I describe a significant enhancement of SimSmith's capabilities. (For brevity, I assume the reader has a passing understanding of SimSmith. For those unfamiliar with the program, I recommend a visit to my web page, www.ae6ty.com/Smith_Charts.html. There are video tutorials on Smith charts in general and SimSmith in particular.)

At the time of that article, SimSmith was a very capable program. It allowed the user enter in a circuit along with antenna simulation or measurements and analyze the system behavior across a range of frequencies. It could draw Smith charts as well as SWR charts. It lent excellent insight to the behavior of the antenna and a simulated matching circuit. Over the years, I've added to SimSmith: new components, new file formats, new charts... many incremental improvements have been made. However, one significant limitation remained: SimSmith could analyze only the most primitive of circuits: ladder circuits. (See the "Ladder Circuits" sidebar.)

SimSmith was not alone in this limitation, all the cousins to SimSmith (linSmith, QuickSmith, WinSmith, MicroSmith, SuperSmith) were equally limited: they all dealt exclusively with ladder circuits. When I authored SimSmith, this seemed a perfectly logical limitation and certainly simplified the analysis. Over the years, though, I have found that this limitation requires too many compromises.

One of the circuits that kept plaguing me was a simple 4:1 Guanella balun. To a first approximation, the 4:1 Guanella balun could be modeled as just a traditional transformer. But this simple model ignored some of the significant limitations of this common circuit. Unfortunately, the more sophisticated modeling of the Guanella balun cannot be described using a ladder circuit. So in order to analyze the balun, SimSmith needed to go back to school with its older cousin, Spice, as its tutor.

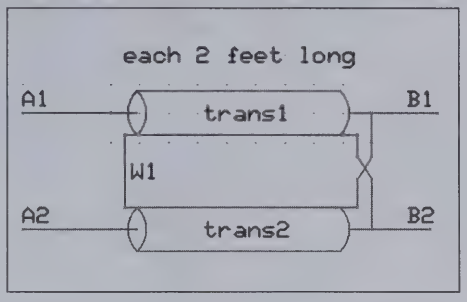


Figure 1

Of course, Spice has been around for many years and I consider it the authority on numeric analysis of circuits. It has capabilities far beyond the trivial needs of a Smith chart program. Specifically: SimSmith needs only to analyze AC, steady state circuits. These are the simplest of problems solved by Spice and the appropriate numerical techniques are easy to understand and program. After a little research I decided that SimSmith could benefit greatly from incorporating these techniques. These new capabilities are incorporated in a new SimSmith circuit element called the "N block"; N standing for *netlist*.

Netlists are simple text files that describe a circuit. There are dozens of netlist formats but they are all very easy to master. SimSmith looked to Spice for the basic inspiration of the netlist format. SimSmith doesn't take spice decks directly, but a spice deck can be easily converted to a SimSmith netlist. Because netlists do not convey graphic information they can be difficult to understand upon inspection. Fortunately, SimSmith netlists tend to be quite small so confusion is rare.

Explaining netlists is best done by example. The first step should be to sketch up a schematic and give names to all the components and to the wires connecting them together. Figure 1 shows a schematic for the common 4:1 Guanella balun. It consists of two transmission lines connected in parallel at one end and in series at the other. I have drawn them as coaxial transmission lines but they can be twisted pair or untwisted pair in actual implementation.

Having drawn the schematic it is a simple matter of typing in the netlist. SimSmith's netlists are just a list of components along with their values and the names of the wires connected. Here is the netlist for the balun:

```
trans1 A1 W1 B1 B2 2;
trans2 W1 A2 B1 B2 2;
```

In SimSmith netlists, the first word on a line indicates the type of component; here the "trans" means it is a transmission line. The "1" and "2" after the "trans" are used to differentiate multiple instances. The "trans" component takes at least 5 arguments: the two wires connected at one end, the two wires connected at the other end, and the length. Additional arguments may be provided as will be shown below.

The two lines above describe our circuit but we have not yet told SimSmith how our circuit is connected to the other SimSmith components. The SimSmith N Block has two ports called P1 and P2. Connections to these two ports are described using the "P" component:

```
trans1 A1 W1 B1 B2 2;
trans2 W1 A2 B1 B2 2;
P1 A1 A2;
P2 B1 B2;
```

At this point we have described the circuit inside the N block and how that circuit is connected to the rest of our SimSmith circuit. Figure 2 shows what happens when we add an N block to a SimSmith circuit and type in the netlist above.

The N block is just another SimSmith block. It has two ports (P1 and P2) and a set of "parameters." The first parameter is the netlist itself. Clicking on that first parameter will bring up a small text window used to edit the netlist. Below that are a set of numeric parameters named a,b,c, etc. These parameters can be used inside the netlist. These numeric parameters can be modified and even used as sweep variables just like other SimSmith component parameters.

Now look at the lower left hand side of the figure and you'll see a "WARNINGS:" block. Whenever SimSmith wants to tell the user of a problem, it displays this block. (When viewed in color, the warning and all the text in the netlist would be dis-

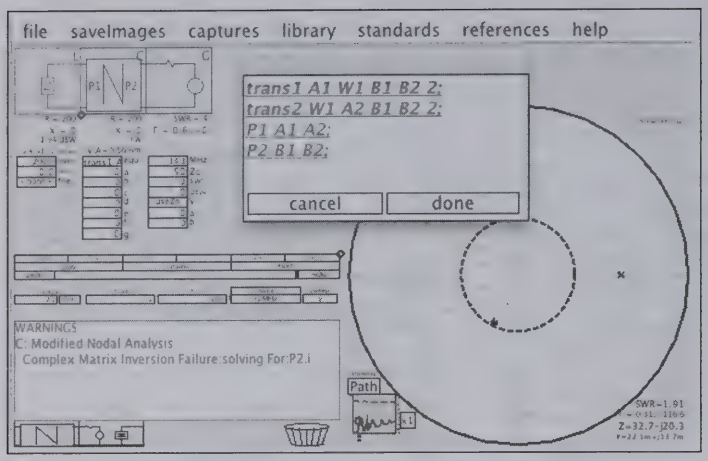


Figure 2

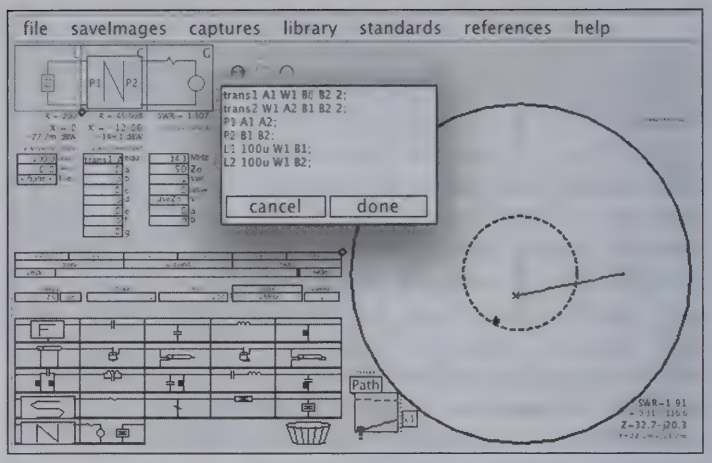


Figure 3

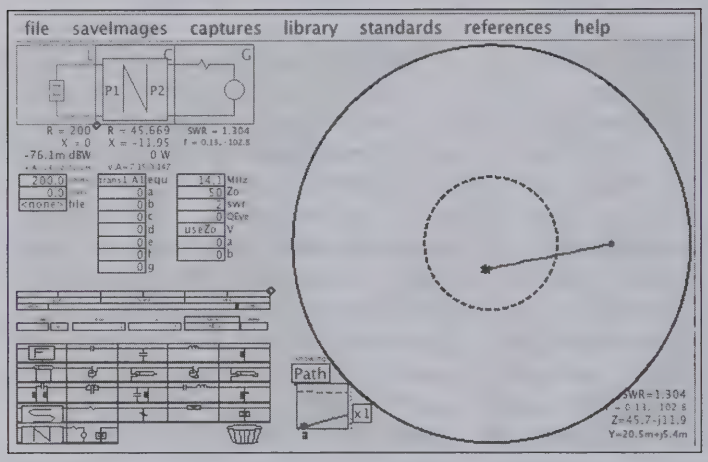


Figure 4

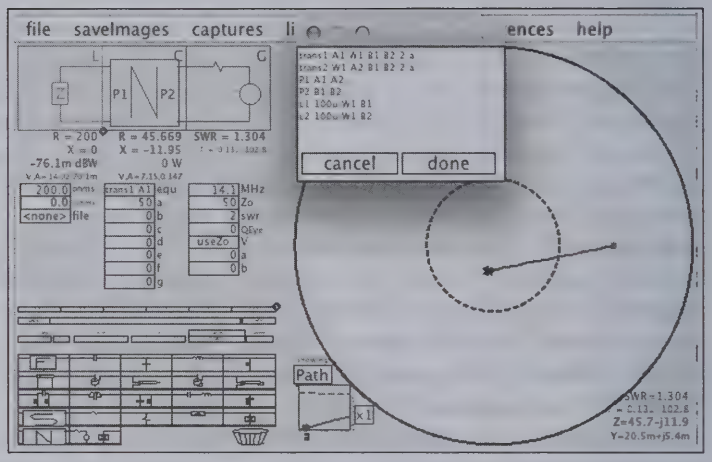


Figure 5

played in red.) In this case, SimSmith complains that it cannot solve for the current flowing through P2. Why would this be?

The reason for this error takes a little explanation. In general, SimSmith fails to analyze a circuit any time a voltage is undefined. It turns out that the voltages on B1 and B2 are undefined because the transmission lines are ideal; there is no common mode connection between the ends. (Yes, the voltage BETWEEN B1 and B2 is defined but not their absolute voltages and SimSmith works with absolute voltages.)

Bottom line, SimSmith doesn't like undefined voltages. To eliminate the error, we simply need to eliminate the floating node. Let's go ahead and model the common mode connection provided by the shield. We will assume the balun is constructed by winding the transmission line through a high permeability core and so the common mode inductance will be quite high. I'll assume 100 uH for now.

After adding in these inductors we have Figure 3. As can be seen, the warnings have gone away. (Note: floating nodes are, by far, the most common problem in this type of circuit analysis. I used a circuit that had these problems specifically to demonstrate the problem and a example of how it can be solved).

Figure 4 shows an error free circuit. Note that I have set the load impedance to 200 ohms. Our N block was supposed to be a 4 to 1 impedance transform. But… when we look at the impedance at the generator on the right, SimSmith does not show an impedance of 50 ohms. What went wrong?

A natural reaction is to blame the common mode inductors but it turns out that would be wrong. You can quickly convince yourself by adjusting the inductance to a very high value, say 1 MegaHenry; it won't change a thing. No, the problem is more subtle and represents a common error made by people constructing Guanella 4:1 baluns: the impedance of the transmission line is wrong. A little research shows that the characteristic impedance of the transmission line is actually a critical parameter for the proper operation of this type of balun. We could just plug in the right answer, but it may prove more instructive to see how SimSmith can be used to determine the right value.

First, we need to know how to specify the characteristic impedance of a transmission line in the netlist. Looking back, we see we already specified the connections and the length of the line. In SimSmith, if you provide one more number, SimSmith will take that number to be the impedance of the line. To experiment with that impedance, we want to use an N block parameter. Lets use parameter "a." Figure 5 shows an updated version of the netlist using parameter "a" to specify the impedance of the lines.

Now that we have specified the characteristic impedance of our transmission line using a parameter we can adjust the value and see how it affects the resulting impedance. Figure 6 shows what happens if we set the impedance lower.

It is clear that setting the characteristic impedance lower doesn't help. The natural conclusion is that it should be set higher

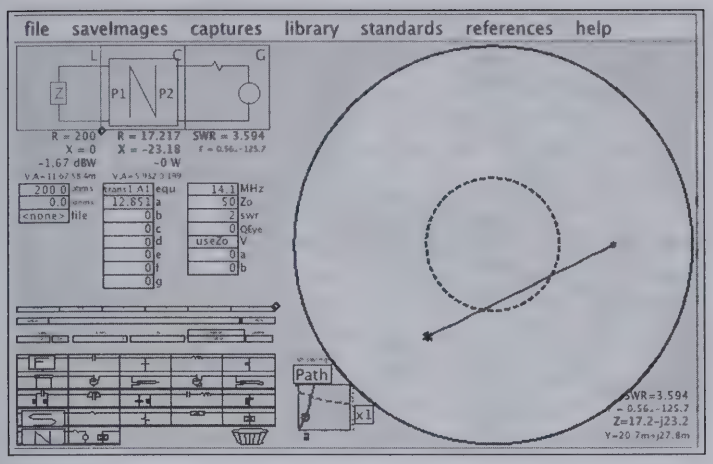


Figure 6

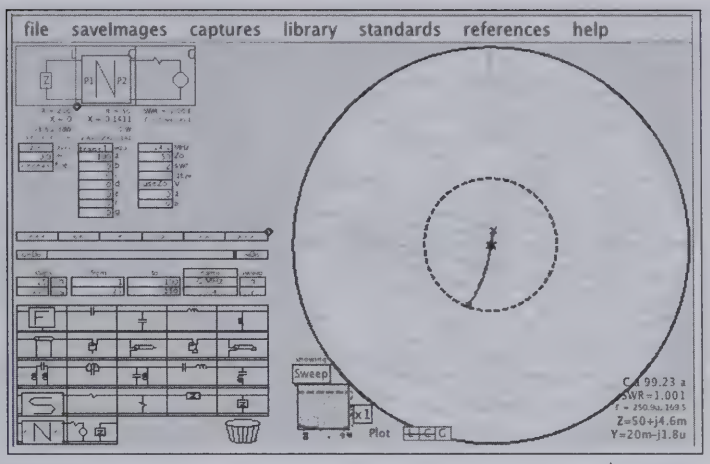


Figure 7

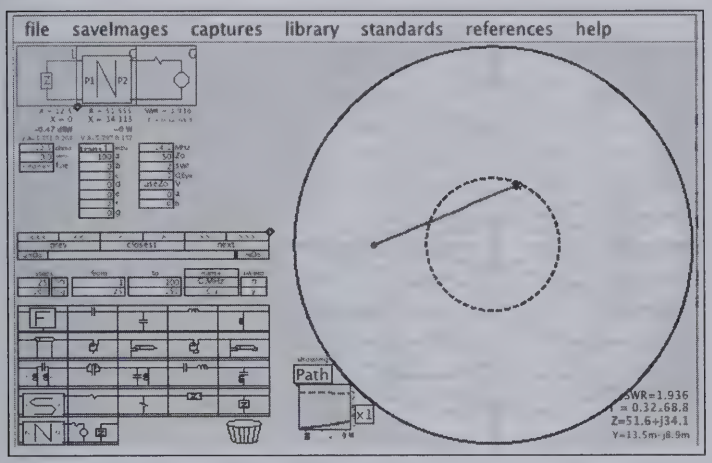


Figure 8

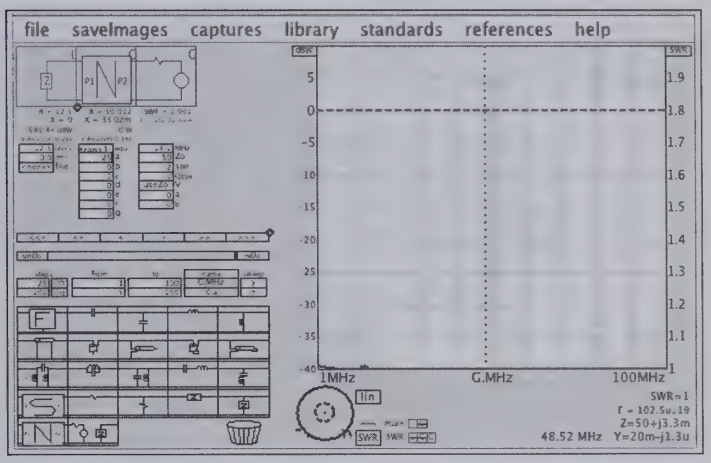


Figure 9

and, ultimately, setting it to 100 works out to be perfectly. Just for fun, we can use SimSmith to sweep the characteristic impedance to see how the balun works across a range of impedances. Figure 7 shows what happens when the characteristic impedance varies from 25 to 150 ohms.

We have determined that the best characteristic impedance for our transmission lines is 100 ohms, at least in this case. Out of curiosity, lets see what happens if we reverse the balun and use it to transform a 12.5 ohm impedance (say from a yagi) up to 50 ohms. Figure 8 shows the netlist and the resulting Smith chart. Note that all I did was reverse P1 and P2…

It is evident in Figure 8 that we again have a problem with the characteristic impedance of our transmission line. We can use the earlier methods to determine the correct impedance. It turns out the right answer is 25 ohms.

Having chosen the correct transmission line impedance we might want to see how it works across a range of frequencies. As Figure 9 demonstrates, the properly designed Guanella balun has extremely wide bandwidths. Indeed, without putting more details in our netlist model, the Guanella bandwidth is infinite! This is why this type of balun is so popular, it does not significantly restrict bandwidth but remember: that is only for a single impedance!

We can use the N block to explore other types of impedance matching networks as well. For example, another type of balun is the Ruthroff. The circuit for the Ruthroff balun is shown in Figure 10. This type of balun is often used on Yagi antennas. The netlist is straight forward and shown in Figure 11.

In addition to the Ruthroff balun netlist, Figure 11 also shows the impedance transformation bandwidth from 1 to 100 MHz. As can be seen, the utility of the Ruthroff balun is frequency limited, it fails entirely at higher frequencies.

The N Block allows the analysis of other circuits not previously possible in SimSmith. Another example might be the auto transformer shown in Figure 12.

This type of transformer is often used in matching end fed antennas. The SimSmith N block does not provide a "transformer" component. Instead, it follows the Spice methodology and allows inductors to be "coupled" using a coupling coefficient. For most purposes, a coupling coefficient of 1 (which is to say "perfect") is assumed.

Figure 13 shows the netlist and resulting Smith chart. Notice that I used the parameter variable "a" so I could adjust the impedance match. Notice, also, that there is an inductive component of about 3 ohms in the resulting impedance. This can be viewed as the "magnetizing" inductance of the transformer.

As a final illustration of the capabilities

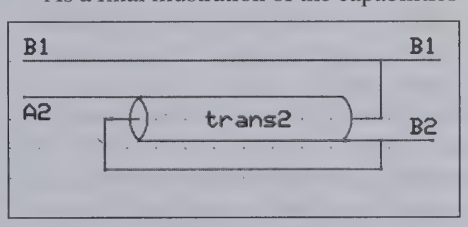


Figure 10

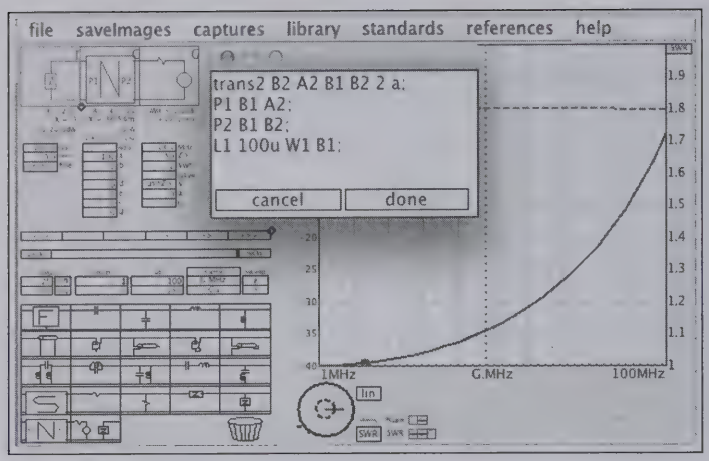


Figure 11

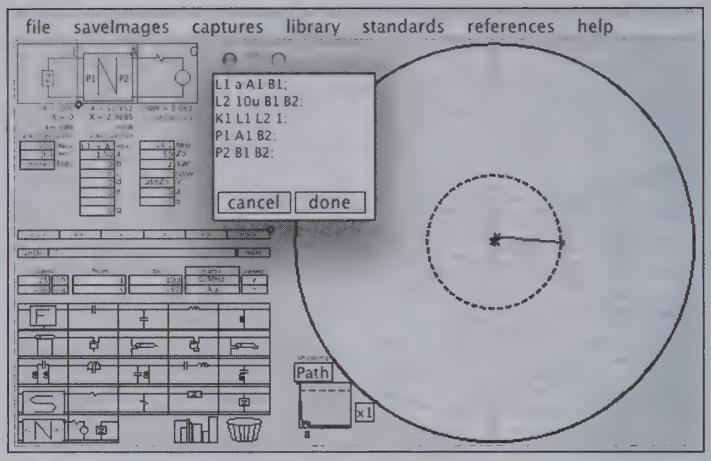


Figure 13

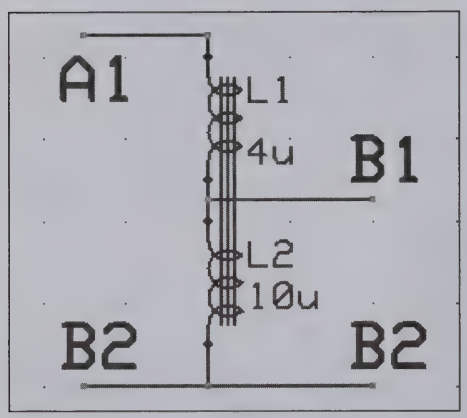


Figure 12

```
//ZMatch
        $A = 21.5n;                 // Al of the toroid.
        P1 out gnd;                 // yes, it should float but we'll ignore this.
        P2 mid gnd;                 // input side.
        Ctop a*1p top bot;          // Ctop I put 'pF' here…
        Cbot a*1p mid bot;          // Cmid    "
        Lout b*b*$A out gnd;        // b turns
        Ltop c*c*$A top mid;        // c turns on top inductor.
        Lmid d*d*$A mid gnd;        // d turns
        Lbot d*d*$A  gnd bot;       // d turns here as well.
        K0 Ltop Lmid Lbot Lout g;   // coupling coefficient…
```

Netlist

of the SimSmith N block, lets take a look at the Z match tuner. Figure 14 shows the schematic. This is probably about as complicated a circuit as one might reasonably describe in SimSmith. I have left out some of the options so as to simplify the circuit somewhat.

This particular ZMatch will be using a powdered iron toroid. The Al for this toroid is 215 uH/100 turns. Converting this to Al/n^2 is 215/10000 which is 21.5 nH/n^2. I put this in as a variable $m in the netlist.

As can be seen from the schematic, there are four inductors and two capacitors. I specify their turn counts and their values using N block parameters as listed.

As expected, at the heart of this circuit is the toroid but hidden within that heart is a little respected parameter, namely, the "coupling coefficient." The coupling coefficient describes how well connected (magnetically) the inductors are. A 1 means perfectly and a 0 means not at all. I had always thought things were pretty close to 1 most of the time. In writing this paper I found that for powdered iron cores, even the best bifilar would transformer has a coupling coefficient of around 0.75. Poorly wound transformers could have a coupling coefficient down around 0.1. Using a N block parameter to specify the coupling coefficient allows us to experiment with this critical value.

Lets dive into the netlist (see above). Most of the netlist is fairly self explanatory but a few fine points should be pointed out:

- The "local variable" $A is used to specify the Al of the toroid.
- Inductors Lout, Ltop, Lmid, and Lbot have inductances calculated from the number of turns. The number of turns is specified by the appropriate parameter.
- The capacitances are specified by the N bloc parameters as well. However, I didn't want to have to always type "p" in the parameters so I multiply the parameter value by "1p" in the netlist.
- The coupling coefficient is specified using the "g" paramter. It is interesting to play with.
- The "Cser" is NOT in the netlist! I used a normal capacitor with SimSmith to make it easier to control.

Having a ZMatch model in SimSmith is very informative. With it, we can explore its performance on the various bands. For example, Figure 15 shows that the SWR bandwidth of this implementation is only about 20 kHz on the 10 meter band. Figure 16 shows that the SWR bandwidth on 40m is much wider at around 1.8 MHz.

The above measurements are true for a 25 ohm load. However, what happens if the load is not 25 ohms? With this model we can sweep through possible load impedances. Figure 17 shows a sweep of 6.9-7.5 MHz and 37.5 to 115 ohms. This range covers most simple wire antennas.

Summation

Over the last few years, SimSmith has expanded its capabilities in many dimensions. The most recent improvement, the Netlist Block, has greatly expanded the range of circuit that can be analyzed. With a generic netlist entry, multivariable sweeping, and Smith chart display capabilities, SimSmith version 9 is more flexible and more informative than ever before. ●●

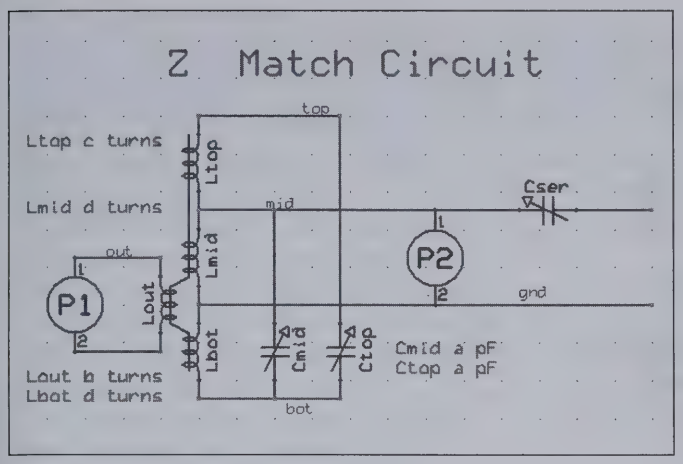


Figure 14

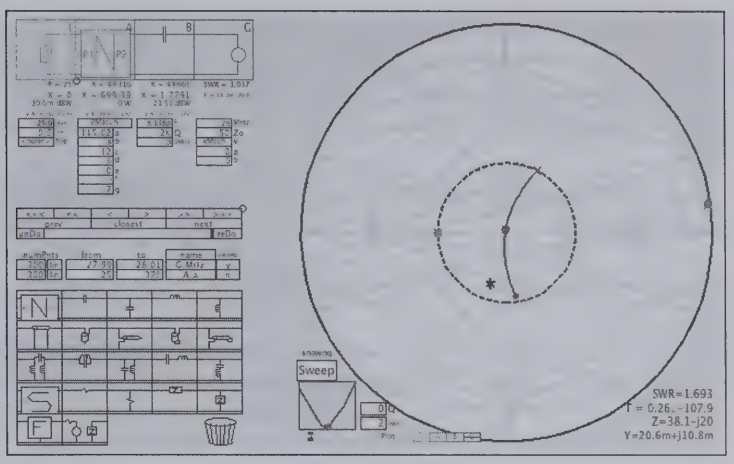


Figure 15

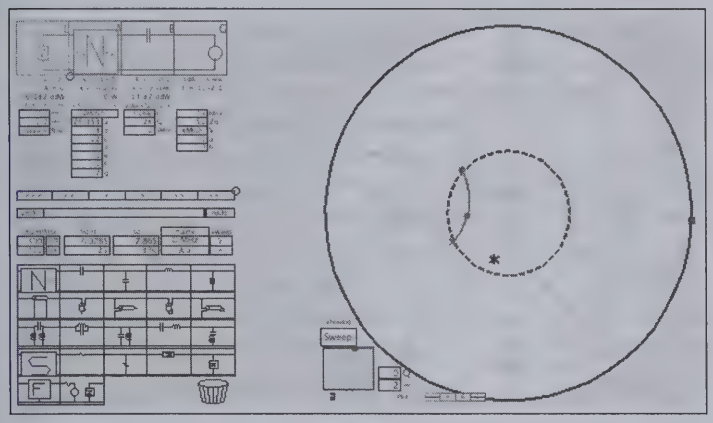


Figure 16

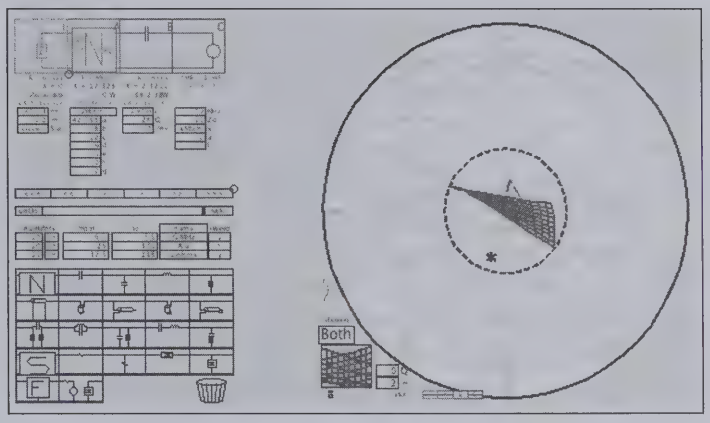


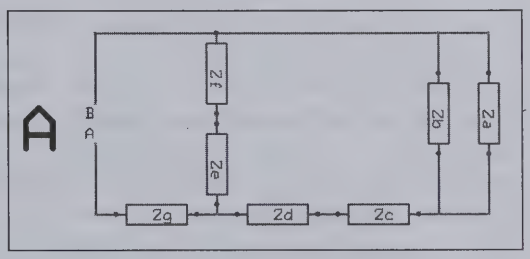
Figure 17

Sidebar: Ladder Circuits

Impedance of Ladder Circuits

Ladder circuits (so named because of their schematic image) are among the most easily analyzed circuits in electronics. Analysis of a ladder circuit consists of the repeated application of just two formulas: the familiar "series" and "parallel" equivalent impedance formulas. For review:

For series impedances: Zeq = Za + Zb
For parallel impedances: Zeq = (Za Zb)/(Za + Zb)



Analysis of a ladder circuit is easy (if tedious). Visually examine the circuit and find a place where you can apply one of the above formulas. Each time you apply a formula, replace two components with one. Eventually, you will reduce the entire circuit to a single component; the "equivalent impedance" of the entire network.

These formulas and techniques apply to reactance and complex impedances without change.

Here is an example. Lets start with this circuit. Suppose we would like to know the impedance seen between points A and B ladder Figure A; there are three reductions which can be done:

Za in parallel with Zb to get an equivalent Z1
Zc in series with Zd to get an eqivalent Z2
Ze in series with Zf to get an equivalent Z3

Which leaves us the circuit shown in Figure B.

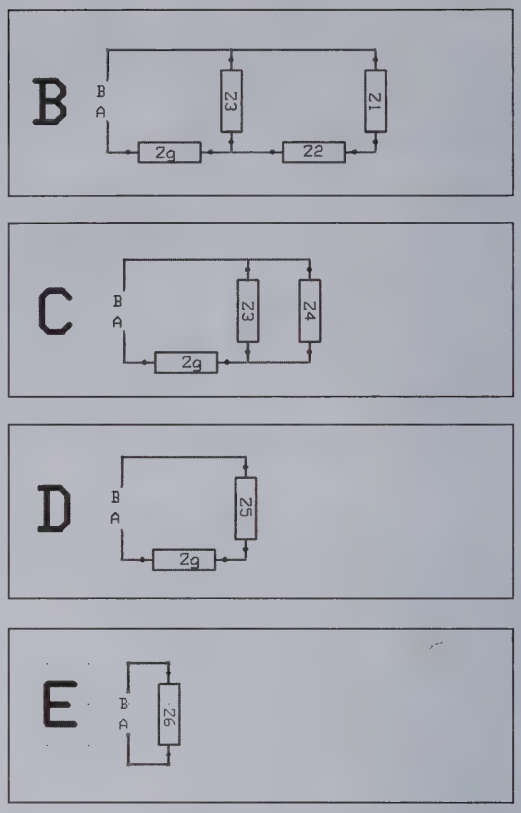
Now, apply the series formula to Z1 and Z2 to get an equivalent Z4 which results Figure C.

Now, apply the parallel formula to Z3 and Z4 to make an equivalent Z5 with the results in Figure D.

And finally, apply the series formula to Z5 and Zg to get Z6 as shown in Figure E.

As you can see, a seemingly complex ladder circuit can easily be reduced used only the repeated application of the series and parallel impedance formulas.

Virtually every Smith chart program available analyzes only ladder circuits. SimSmith version 9 extends Smith chart analysis to arbitrary linear circuits.



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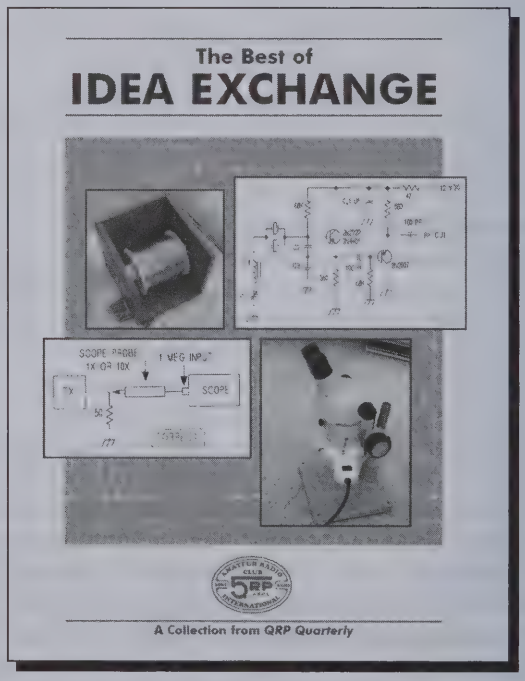

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The St. Louis "Slide WhiSTLe" Capacitor

Jon Poland—NØWL

I have the remarkable good fortune of being a member of the St. Louis QRP Society. This group of wonderful radio enthusiasts is located in the St. Louis, MO, area and has been meeting regularly for over 26 years. Through association with this group I became interested in small transmitting loop (STL) antennas—aka mag loops. Since I live in a CCR subdivision, I decided that I should put a STL antenna in my attic. This started a quest.

Of course I wanted an antenna that would cover as large a frequency range as possible, specifically; I wanted to cover the 40m through 10m bands. In my research I discovered that some others have had difficulty creating an antenna that would cover that wide a range. I came to realize that the major contributor to the problem was that it is very hard to find a commercially available capacitor that can vary the capacity by the 50x range needed by such a broadband antenna. (My antenna needs a capacitor that will go from roughly 4 pF to over 200 pF!) While it is easy to get the lower frequencies, reaching 30 MHz is tough because most variable capacitors aren't designed to reach high capacitance and sacrifice the low capacitance required at high frequencies.

And so I set out to design a variable capacitor that would meet my needs. While there is nothing new in the methods I use, the combination of several features results in a new style of capacitor that, I believe, is unique to amateur radio.

After a lot of research and building several prototypes, I came to the conclusion that I could easily build several styles of variable capacitor—including the traditional rotary gang capacitor. But the design I settled on is a version of the "trombone" capacitor.

A trombone capacitor is a common design for loop antennas. In this style of capacitor you have two tubes that slide together (with a dielectric gap). As you move the tubes together or spread them apart, the capacitance changes. For STLs you generally use a pair of tubes with the ends of the inner tubes connected together (Figures 1 and 2). This looks and acts like a trombone slide. My capacitor is a modified trombone with these features:

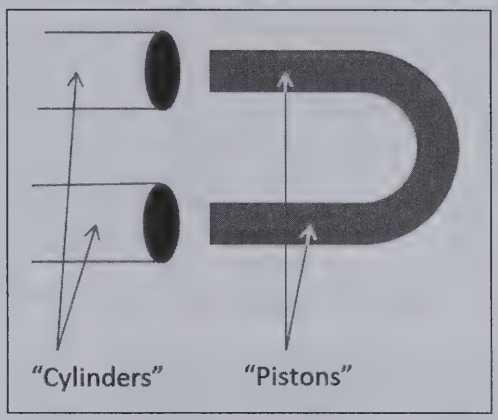

Figure 1—A typical 2-gang "trombone" capacitor.

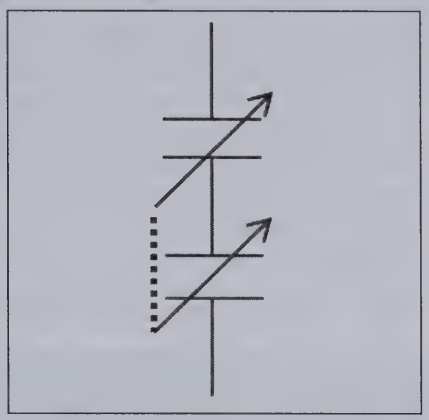

Figure 2—Schematic symbol for the 2-gang trombone.

- I use readily available hobby store thin-wall brass tubing
- I use six pairs of tubes
- The tubes are not the same length
- For a dielectric I use 2 layers of 5 mil Dura-Lar sheeting that is readily available

Because of the six pairs of tubes, this capacitor no longer resembles a trombone. To me, it looks more like a gang of slide whistles: hence the name. And as this name suggests; this capacitor is much smaller than a trombone capacitor.

Some Basic Capacitor Theory

A basic capacitor is created when two or more electrically charged conductors are separated by an insulator (referred to as a *dielectric* in a capacitor). Any pair of conductors will have a capacitive effect. This includes antenna feed line, layers of circuit board, our hand and the body of a radio, etc. Of course when we create a capacitor we intentionally want the capacitance, but would like to control it as much as possible and minimize the negative effects of resistance and inductance created by currents in the conductors.

The equation for a simple capacitor is shown in Figure 3; Figure 4 illustrates its construction. From the equation we see that we can increase the capacitance in three ways:

- Increase the surface area of the conductors
- Decrease the distance between the plates
- Find a material for the insulator that has a higher dielectric constant

A Better Dielectric

Notice that two of the above elements relate to the dielectric. To get a high value capacitor in a small package we need a dielectric that is as thin as possible and is made from a material with a high constant.

Traditionally, air is used for the dielectric in most variable capacitors. We can put the plates pretty close together. A "polyvaricon" capacitor used in small transistor radios uses very thin polyethylene film for the dielectric. A few other dielectric

$$C = 0.224 \cdot \varepsilon \frac{A}{d}$$

C=capacitance (pF)
ε=dielectric constant
A=surface area of plates (in²)
d=distance between plates (mils)

Figure 3—Capacitance equation.

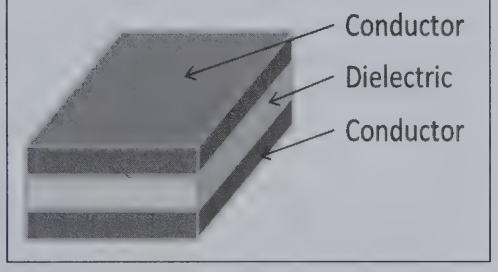

Figure 4—Basic capacitor construction.

Material	Dielectric Constant	Breakdown Voltage per mil (0.001")
Air	1.0	21
Vacuum	1.0	?
Glass	7.6-8.0	200-250
Water	76.5-80.0	?
Mineral Oil	2.7	200
Paper (bond)	3.0	200
Polyethylene	2.3	450
Polystyrene	2.6	500
Epoxy Circuit Board	5.2	700
Teflon	2.1	1000
Mylar	3.0	7500
Dura-Lar brand Mylar	3.2	7000

Table 1—Dielectric constant and breakdown voltages for various materials.

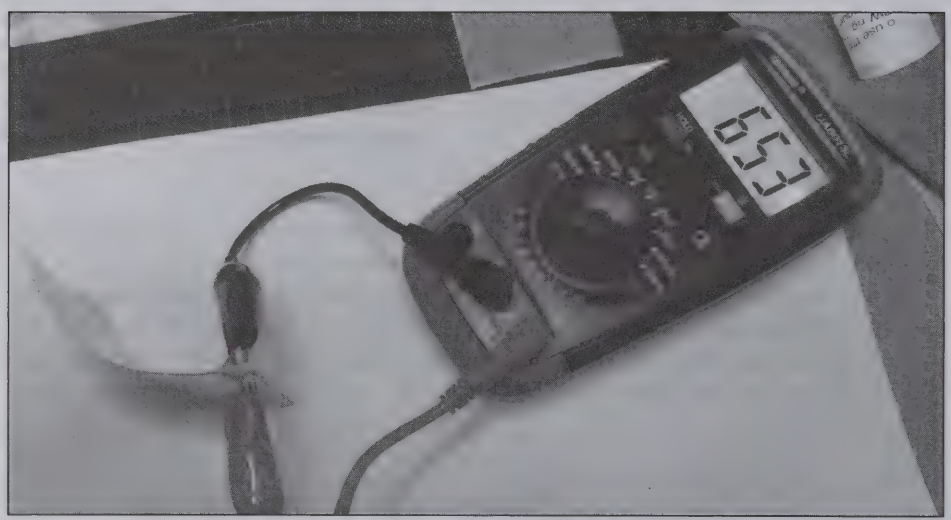

Photo 1—A 6 sq. in. capacitor made with 5 mil Dura-Lar as the dielectric.

options are shown in Table 1. This table also introduces a negative characteristic of dielectrics: the thinner they are, the lower the voltage they can tolerate. This is the "breakdown voltage." Different materials have different breakdown voltages. The breakdown voltage of the dielectric becomes a conflicting design constraint of dielectric selection: to tolerate high voltages we need to select our dielectric carefully and make sure that the dielectric is thick enough. For example, a 100 watt mag loop antenna will have roughly 4,300 volts across the capacitor. To achieve this voltage with air, the plate separation must be greater than 205 mils (0.205"). For a polyvaricon we would need 10 mils (0.01") but most polyvaricons use sub-mil dielectrics.

Mylar and Teflon® make great dielectrics. And they are commercially available. You can purchase Teflon sheets from Wal-Mart in the craft aisle. It is used as an insulator when ironing appliques (ask your XYL). Mylar is also readily available, comes in various thicknesses and has an even higher breakdown voltage than Teflon. Because Mylar can be used by artists as a tracing paper, canvas replacement, etc., it is easy to find. I use Dura-Lar brand mylar that is available from artist supply stores and Amazon.com. A single package of either Dura-Lar or Mylar can make many capacitors.

Most of the capacitors I have built use 3 mil (0.003") thick Dura-Lar as a dielectric. This has a breakdown voltage of 21,000 volts! A 1,500 watt mag loop has a maximum voltage of only 16,644 volts. So this sheet of plastic should be able to handle full legal limit: however, I have no intention of testing this!

To test the theory, I built several simple capacitors using various materials. Photo 1 is a typical example. This capacitor is constructed by laminating a 5 mil sheet of Dura-Lar between 2 pieces of 2" x 3" adhesive backed copper tape. In the photo you can see the measured capacitance of 653 pF. Working backward using the equation in Figure 3, the measured dielectric constant is 2.4 instead of the expected 3.2. However this is not too surprising because the adhesive backing on the copper tape introduces an air gap that lowers the constant. But it does not reduce the 35,000 volt breakdown voltage. This capacitor measures 108 pF per sq. in. And I can create any size capacitor by increasing or shrinking the amount of foil I use. The cost of this capacitor is less than $0.25 and took less than two minutes to make.

Design Considerations

I decided that I wanted to build a STL using a 10 ft length of 1/2" ID soft copper tubing to cover the 40m though 10m bands. Using my own version of AA5TB's loop calculator, I decided that I needed a capacitor with at least 202 pF or 2 capacitors with 404 pF in series. To reach the top of the 10m band, a minimum C of 3.7 pF was calculated (or 2 each 7.4 pF in series).

By using thin wall brass tubing for the capacitor, I keep the dielectric gap between the tubes very small. This plus the Mylar dielectric is the key to reaching high values of C in a small space.

I chose to build my capacitor from 21/32" diameter brass tubing for the outer cylinder portion of the capacitor and 19/32" tubing for the inner piston. This is the largest diameter thin wall tubing that you can find in a hobby store. When nested, there is just enough space between 2 tubes to put a double-wrapped sleeve of 5 mil Dura-Lar between the tubes; a total of 10 mil thickness. The measured capacitance of this arrangement is 57.6 pF/inch. To reach my desired 404 pF per slider, I would need a total length of ~7". Rather than use a single tube, I decided to use 3 tubes: 2 are 2" long and the 3rd is 3-1/2" long. Splitting the single capacitor into 3 capacitors of unequal length is probably the most significant feature.

In essence this design uses 6 capacitors. There are 2 series sets of 3 parallel capacitors (see Fig. 5). Four of the capacitors have 2" long cylinders through which the piston passes. The other 2 capacitors are 3-1/2" long. For minimum C, all pistons are completely out of the cylinders. To increase C, all 6 pistons are inserted into all 6 cylinders at the same time, and C increases at a rate of about 90 pF/inch. But when the pistons reach the end of the short

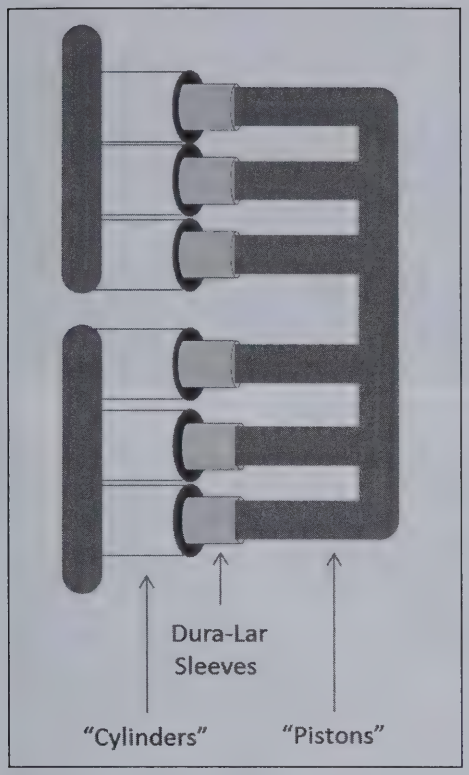

Figure 5—The Slide WhiSTLe 6-gang capacitor.

cylinders, they go right out the end and do not add anymore to the total C. Meanwhile the piston on the long cylinders is still inside and still contributes C, now at the lower rate of about 30 pF/inch.

This is a great thing for the capacitor to do because it makes the antenna easier to tune in the 40M band! Anyone who has used a STL knows that the bandwidth gets extremely narrow at low frequencies making them tricky to tune. The St. Louis Slide WhiSTLe minimizes this problem by slowing how quickly C changes on the low band! During tuning it is as if the 40M band is 3 times as wide.

You could get really fancy with the design. My capacitor only offers wide tuning for the 40M band. If you wanted you could use 3 different lengths of tubing and have medium tuning on say the 20M and 10M bands. Or you could use more than 6 capacitors and have custom tuning for each band! Six was more than enough for me.

The use of the Dura-Lar insulation has several advantages:

- It would be impractical to build an air-gap capacitor with such a small dimensions. Even if you could, the small gap would severely restrict the power you could use with the antenna. Dura-Lar is 10x better as an insulator than air. The rated insulation for 10 mil of Dura-Lar is 70,000 V! Using AA5TB's spreadsheet again, we see that, theoretically, this amount of Dura-Lar could support over 25 kW (yes kW) of power.
- My measured dielectric constant for Dura-Lar is about 2.5. This means that the capacitor is 40% smaller than an equivalent air-based capacitor. Small is better because it means that the capacitor has less impact to the radiation field of the STL.
- I have the Dura-Lar extend on either side of the cylinder by at least 1/2". This helps with insulation, but the most important benefit is that I can pull the piston well away from the cylinder. This allows extremely low capacitance for the low bands.
- Finally Dura-Lar is slippery. The the pistons slide smoothly in the sleeves.

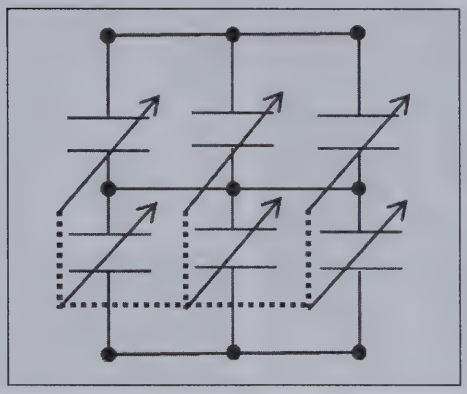

Figure 6—The Slide WhiSTLe schematic diagram.

Construction

(Design and assembly are documented in Photos 2-7 on the next page.)

I mounted my 6 pistons and 6 cylinders into two bases of 5/8" thick HDPE plastic cutting board. (You can substitute 1/2" aircraft plywood from the hobby store.) The pieces were screwed together as pilot holes were drilled into the two bases using a drill template. This was done to make sure that all tubing would be perfectly aligned. I do not have 21/32" or 19/32" drill bits so I used 5/8" and 9/16" bits to make the holes and enlarged them with sandpaper after drilling. The tubes were friction-fit into the bases. I left ~1/4" of cylinder tubing extending out the end. The piston tubing was fit flush with the base. If the holes in your bases are too large, just wrap some Scotch Tape around the tube to get the proper fit.

I tapped a hole in the center of the cylinder base to support a 1/4-20 threaded rod. The threaded rod is attached to a geared motor that is mounted to the back of the piston base. I used nylon lock-nuts on the rod to limit travel. You don't want the pistons to go so far in that the Dura-Lar sleeves extensions get crushed; and you don't want the pistons to go so far out that they fall out of the sleeves. Total piston travel is 4" or 80 turns of the rod.

Originally I used 4-1/4" x 6" pieces of Dura-Lar. I decided that these were too large and changed to a 4"x 5" sheet size. You need the Dura-Lar to extend at least 1/2" out on the piston side of the cylinders to allow the pistons to come completely out of the cylinder on the high frequencies. The Dura-Lar sleeve acts as a guide even when the piston is all the way out.

Dura-Lar is springy and it takes a little practice getting it wrapped small enough to fit inside the cylinders. My only suggestion is that you can wrap it into a slight cone shape to get one end in, and then juggle the sheet to get it to slide all the way in.

It is important that the Dura-Lar sleeve doesn't move as the piston goes in and out. I taped the sleeve to the far end of the

(6)	19/32" OD thin wall brass tubing 5" long (hobby shop or Amazon.com)
(4)	21/32" OD thin wall brass tubing 2" long (hobby shop or Amazon.com)
(2)	21/32" OD thin wall brass tubing 3 ½" long (hobby shop or Amazon.com)
(6)	4" x 5" squares of 5 mil Dura-Lar sheet rolled to make 5" long sleeves. (Available from Amazon.com as a book of 25 9"x12" sheets in art supplies)
(2)	2 ½" x 3 ½" pieces of 5/8" thick HDPE: e.g., from a kitchen cutting board (1/2" aircraft plywood may also be used)
(1)	5" long 1/4-20 threaded rod
(1)	Motor or knob to turn the threaded rod and piston assembly
(12")	14-gauge copper wire (approximate length needed)
Misc.	1/4-20 lock nuts, washers and other hardware

Table 2—Materials list.

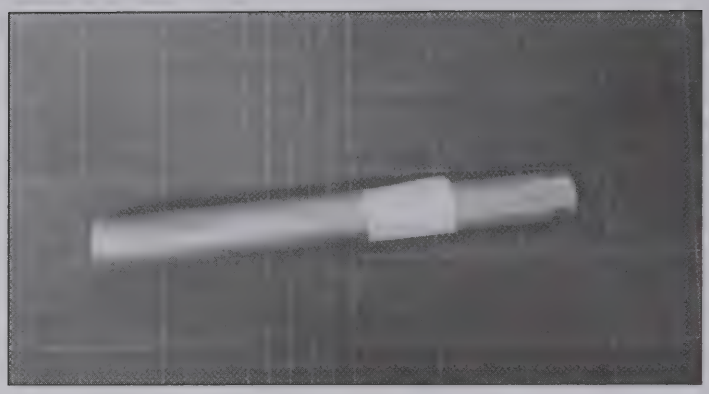

Photo 2—A single trombone section.

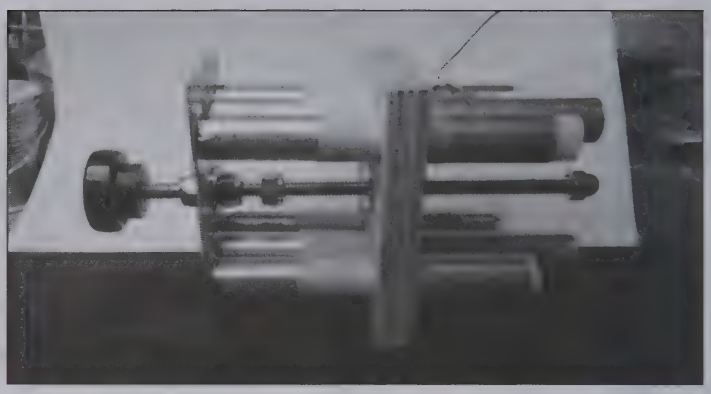

Photo 3—My first complete design.

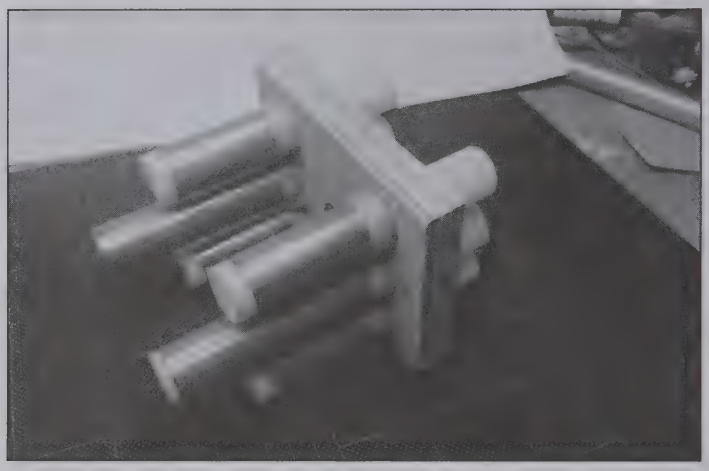

Photo 4—Version 1's cylinder assembly. White sections on the sleeves is Dura-Lar, tape is used for friction fit to the wood.

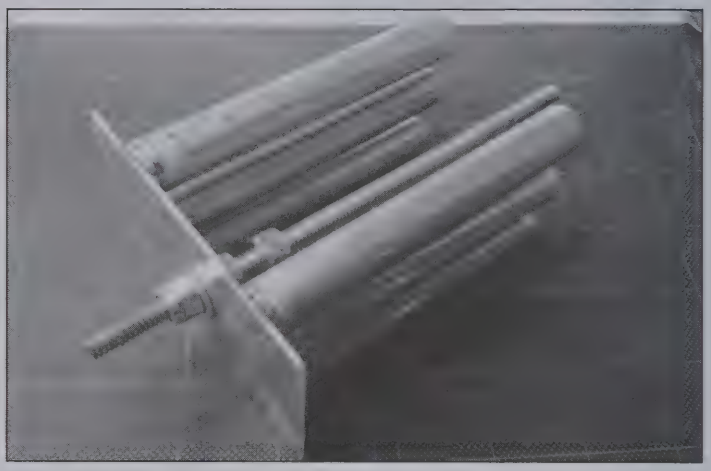

Photo 5—Version 1's pistons used p.c. board material as a base. Alignment was difficult and this method was abandoned.

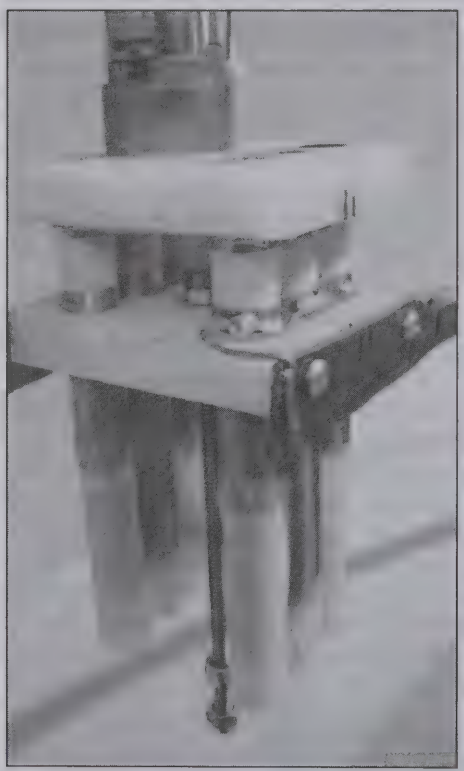

Photo 6—Version 2 with pistons fully inserted (maximum capacitance; lowest resonant frequency).

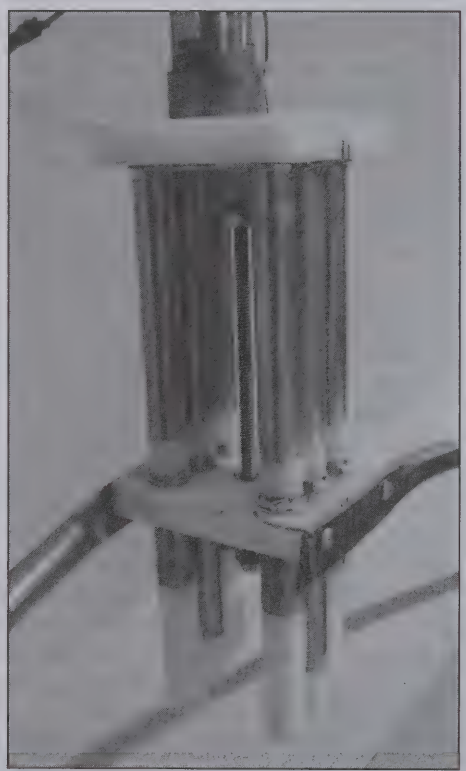

Photo 7—Version 2 with the pistons fully withdrawn. Note how the copper loop is attached.

cylinders to prevent any slipping.

In my antenna, the copper tubing of the loop is screwed into the cylinder base. This means that the pistons, the piston base, and the motor all move. I built it this way to minimize the impact to the antenna pattern. But if you wanted, you could attach the loop to the piston and move the cylinders. You could also eliminate the motor and use a knob on the threaded rod for hand tuning.

Even though the longest cylinder is only 3-1/2", I adjust the travel of the pistons to about 4". This allows for over-run in both ends of the piston travel.

I used a miter saw with a panel blade to cut the HDPE cutting board. I also discovered that the same saw and blade was the easiest way to cut the tubing; with safety glasses and gloves on of course. Do NOT try to cut thin wall tubing with a plumber's tubing cutter—it distorts the tubing too much for this application.

Finally, I soldered the pistons to each other with 14-gauge copper wire. I also used 14-gauge wire to connect each of the 3-gang cylinders to the copper tubing of the loop.

Results

I am extremely pleased with the results! As constructed this capacitor will tune my STL from 6.9 MHz to 34.7 MHz. If you look closely at the C vs. Turns graph in Figure 7, you will see 2 distinct points where the slope of the curve changes. From turn 0 to about turn 32, only 2 of the 6 capacitors are changing. This covers the 40m band at a slow tuning rate. At about 8 MHz, all 6 capacitors take effect and the tuning is faster.

I used a small C meter I bought at Dayton for $20 to measure capacitance. I used a SARK-110 Vector Impedance Antenna Analyzer to measure resonant frequency of the STL after it was connected to my 10 ft. circumference loop made of 1/2" hardware store copper tubing. Knowing frequency, you can reverse engineer the AA5TB spreadsheet to calculate that the actual minimum C of the Slide WhiSTLe is actually 0.7 pF. This makes this the only capacitor I know of that can go from 0.7 pF all the way up to 210 pF!

The change in tuning rate occurs at about 32 turns in the charts. It is hard to see in the right-hand graph but the tuning change happens at about 7.75 MHz

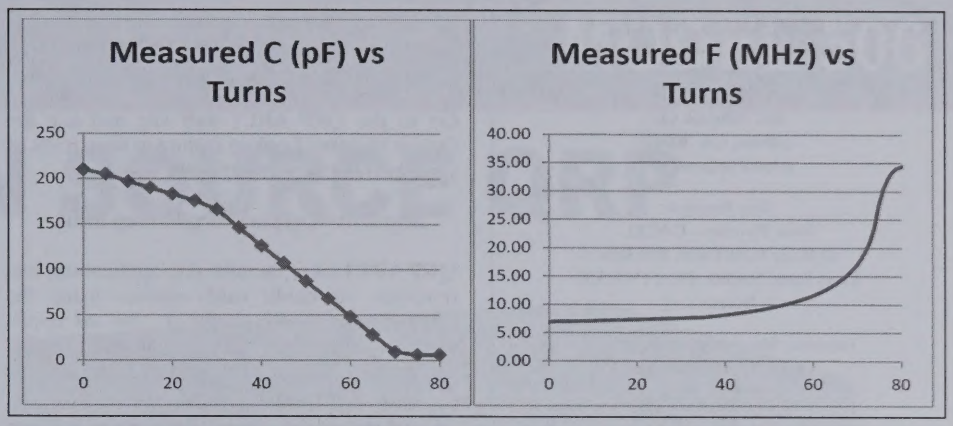

Figure 7—Plots of capacitance and tuning vs. number of turns.

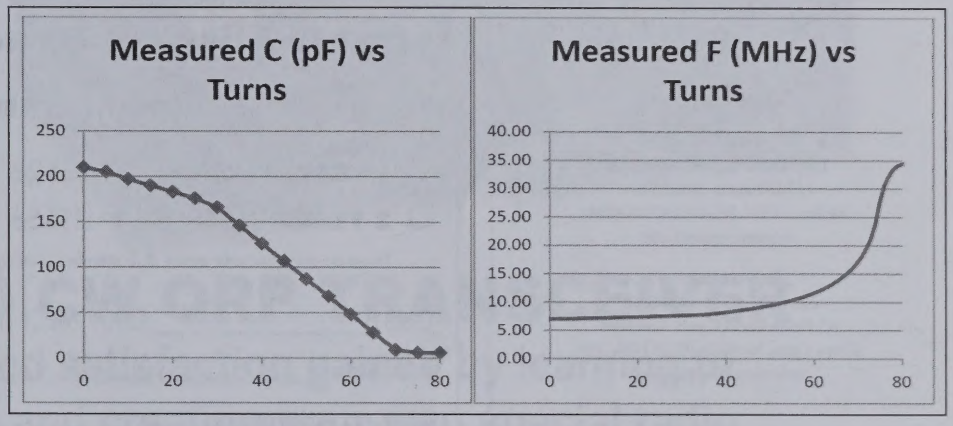

Figure 8—Predicted bandwidth and tuning sensitivity plots.

Additional Considerations

With my motor it takes about 30 seconds to travel all 80 turns. This particular motor has a shaft encoder and gearing to allow 1000 steps per turn. My goal is automate the tuning of my antenna using measured SWR and F.

Having 80,000 measurable steps across the bands will be nice to have but it begs the question of what is really necessary and could a stepper motor with lower resolution be used in this design. The graphs in Figure 8 show calculated bandwidth vs. frequency and also the minimum number of steps per turn to guarantee overlap of bandwidth for every value of F.

The graphs show that the 20M-15M bands need 32 steps per turn to keep every frequency within bandwidth. Thirty-two steps per turn is well within the capability of a stepper motor to accomplish. This also shows that the most sensitive band to tune is the 20M band rather than the 40M band as with traditional STL capacitors

I intend to use this antenna for QRP and won't be testing it above 5 watts. The design specs suggest that it should run QRO and I've tried to build it considering extremely high voltages. Part of the reason for making sure the Dura-Lar sleeves extend past the ends of the tubing is to make sure that there is no gap for arcing. Would someone with a high power transmitter be willing to see how high it can actually go???

Criticisms

No design is perfect! There is discussion on the internet that any large capacitor will impact the radiation pattern of a STL. However, this is a very complex problem and I've seen no modeling or measurement to justify the concern. Certainly it must be an impact but no one can say how much. I've see air-dielectric trombones that are as large as the loop they connect to: this design is less than 20% of the loop diameter in worst case. And its dimensions compare closely with that of a vacuum variable capacitor. Somehow I doubt that I will notice the misshaped radiation pattern once the STL is in my attic.

STLs are very sensitive to resistance. I think that I could reduce the resistance in 2 places: use copper tubing instead of brass, and use high gauge wire to connect everything together. Does anyone know where to find affordable thin-wall copper tube?

If I had to do it again, I would increase the total C by about 10%. I don't need the frequencies above 30 MHz and I am really close to my 7.0 MHz lower limit. Also it would be nice if the tuning rate would change closer to 7.3 MHz because it takes quite a few turns to get from 7.3 to the next higher frequency of interest: 10 MHz.

I have found the Dura-Lar to be effective and easy to work with. But perhaps there is a more effective material to use as a dielectric.

Conclusion

This has been a fun project! As I write this, I haven't finished the motor controller circuit. That has to happen before the antenna goes into the attic. I am confident that when it gets there, it will perform just as desired! I hope that these articles provide enough detail for anyone who is wants to design their own. I will love to from anyone who builds one and how it does for them. ●●

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